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Soil Survey of Iowa, Report No. 70—Butler County Soils

P. E. Brown
Iowa State College

J. A. Elwell
Iowa State College

H. R. Meldrum
Iowa State College

R. E. Bennett
Iowa State College

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SOIL SURVEY OF IOWA

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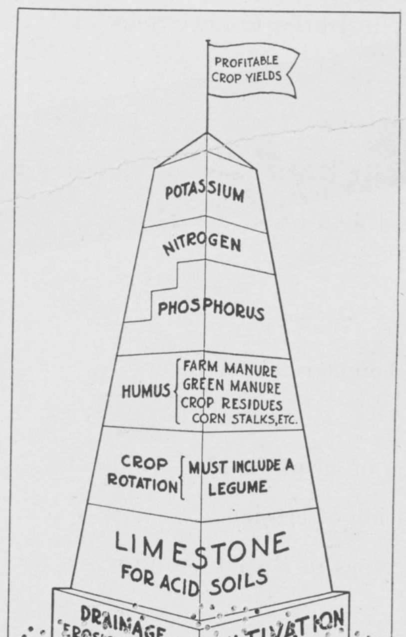
By P. E. Brown, J. A. Elwell, H. R. Meldrum and R. E. Bennett



IOWA AGRICULTURAL
EXPERIMENT STATION
R. M. Hughes, Acting Director
Ames, Iowa

CONTENTS

BUTLER COUNTY SOILS[1]

By P. E. Brown, J. A. Elwell, H. R. Meldrum and R. E. Bennett

Butler County is located in northeastern Iowa in the third tier of counties south of the Minnesota state line and in the fourth tier of counties west of the Mississippi River. It is mainly in the Iowan drift soil area, and hence most of the soils are of drift origin. There is a small acreage of loess soils undoubtedly derived from the Mississippi loess deposit.

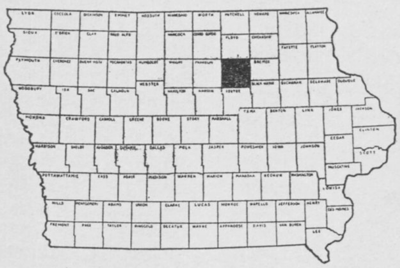


Fig. 1. Map showing location of Butler County.

The total area of the county is 581 square miles, or 371,840 acres. Of this area 354,353 acres, or 95.3 percent, are in farm land. The total number of farms is 2,245, and the average size of the farms is 158 acres. Owners operate 37.4 percent of the total farm land, and renters the remaining 62.6 percent. The following figures, taken from the Iowa Yearbook of Agriculture for 1931, show the utilization of the farm land in the county:

Acreage in general farm crops	239,300
Acreage in farm buildings, public highways and feedlots	19,690
Acreage in pasture	93,887
Acreage in wasteland not utilized for any purpose	1,579
Acreage in farm woodlots used for timber only	1,777
Acreage in crop land lying idle	315
Acreage in crops not otherwise listed	547

THE TYPE OF AGRICULTURE IN BUTLER COUNTY

The present type of farming in Butler County combines grain and livestock production and is, therefore, mainly the general farming system. The chief crops grown include corn, oats and hay, the major portion of these crops being fed. A large part of the minor crops grown are also fed on the farms. The main livestock industries named in the order of importance, are pork production, dairying, beef production, sheep production for mutton and wool, and the raising of horses for local demands. The farm income is derived chiefly from the sale of livestock products, and is supplemented by the sale of corn, oats, and other grain crops, some hay, various minor farm and truck crops and poultry products.

There is a considerable acreage in waste land, and much of this might be made productive by the adoption of proper methods of soil treatment. General recommendations cannot be given for the reclamation of such areas as the causes of infertility are various. In a later section of this report suggestions will be given for the best methods of handling unproductive areas in the various soil types. Where the conditions are abnormal, advice regarding desirable treatments for any particular area of land may be secured upon request from the Soils Subsection of the Iowa Agricultural Experiment Station.

[1] See Soil Survey of Butler County, Iowa, by J. A. Elwell of the Iowa Agricultural Experiment Station and E. N. Poulson of the U. S. Department of Agriculture, Field Operations of the Bureau of Chemistry and Soils, 1928. Project No. 241, Iowa Agricultural Experiment Station.

FARM CROPS GROWN IN BUTLER COUNTY

The general farm crops grown in the county in the order of importance are corn, oats, hay, potatoes, alfalfa, barley, soybeans, rye and wheat. The acreage, yield and value of these crops are given in table I.

TABLE I. ACREAGE YIELD AND VALUE OF PRINCIPAL CROPS GROWN IN BUTLER COUNTY, IOWA*

Crop	Acreage	Percent of total farm land of county	Bushels or tons per acre	Total bushels or tons	Average price**	Total value of crops
Corn	121,633	34.33	22.4	2,724,579	$ 0.37	$1,008,094
Oats	76,667	21.64	22.7	1,739,480	0.24	417,475
Winter wheat	184	0.05	20.4	3,752	0.50	1,876
Spring wheat	119	0.03	14.1	1,681	0.45	756
Barley	2,086	0.59	18.9	39,436	0.37	14,591
Rye	848	0.24	9.7	8,223	0.40	3,289
Clover hay***	1,554	0.44	0.54	839	9.38	7,870
Timothy hay	2,716	0.77	0.51	1,385	9.38	12,991
Clover and timothy hay (mixed)***	19,842	5.59	0.69	13,691	9.38	128,422
Alfalfa	1,862	0.62	1.43	2,663	9.38	24,979
All other tame hay	2,017	0.58	0.73	1,472	9.38	13,807
Wild hay	5,616	1.58	0.46	2,583	6.94	17,926
Soybeans sown with other crops	630	0.18	....	......	....	......
Soybeans sown alone	1,873	0.62	....	......	....	......
Soybeans harvested for beans	356	0.10	10.9	3,884	0.67	2,602
Potatoes	686	0.19	32.0	21,952	0.60	13,171
Timothy seed	325	0.09	3.10	997	2.36	2,353
Clover seed***	72	0.02	0.57	31	11.99	372
Sweet clover seed	47	0.01	0.50	25	3.00	75
Sweet clover****	167	....	....	......	....	......

* Iowa Yearbook of Agriculture, 1931.

** Average county farm price for corn, oats, winter wheat, spring wheat, barley, all tame hay, including alfalfa, wild hay, soybeans, timothy seed and red clover seed. Average state farm price for rye, potatoes and sweet clover seed.

*** Sweet clover not included.

**** All varieties for all purposes.

Corn is the most important crop, both in acreage and value. In 1931, it was grown on 34.33 percent of the total farm land, and the average yield was 22.4 bushels per acre. On the better land the yields are always very much larger than this. The most popular varieties are Grundy County White, Dewey White Dent, Silver King, Moore Yellow Dent, Reid Yellow Dent and Ioleaming. Mixed home-grown seed is commonly used. Some Calico corn is produced for feeding.

The second crop in acreage and value is oats. In 1931 oats were grown on 21.64 percent of the total farm land with an average yield of 22.7 bushels. Much higher yields are secured under favorable soil and seasonal conditions. Early or medium-early varieties of Kherson, Iowar and Iowa 103 are the most popular, though some Green Russian oats are grown. Much of the oats grown is fed on the farms, but considerable income is secured from the sale of oats.

Hay is the third crop in acreage and value; timothy and clover mixed being grown most generally. In 1931 this crop was grown on 5.59 percent of the farm land, and the average yield was 0.69 ton per acre. Some clover is grown alone for hay, yielding in 1931, 0.54 ton per acre, on the average. Occasionally clover is grown for seed. Timothy is grown alone for hay on some farms and on a few for seed. In 1931 timothy yielded 0.51 ton of hay per acre. Wild hay was produced on 1.58 percent of the farm land in 1931 with an average yield of 0.46 ton per acre.

Potatoes are grown on practically all farms, chiefly to supply the home demand. In 1931, the average yield was 32 bushels per acre. The principal varieties are Early Ohio, Petoskey, Triumph and Burbank. On considerable acreages in the southwestern part of the county potatoes are grown for market.

Alfalfa is grown on a limited area, and in 1931 the average yield was 1.43 tons per acre. It should certainly be grown much more extensively in the county, as it is a very valuable crop. When the soil is limed and fertilized and the seed is inoculated, the stands secured are entirely satisfactory, and large yields are secured. The Grimm variety is most commonly used.

Barley is a minor crop, being grown in 1931 on 0.59 percent of the farm land. The average yield in that year was 18.9 bushels per acre.

Rye is grown on some farms. The average yield in 1931 was 9.7 bushels per acre. Soybeans are grown alone or with other crops, chiefly corn, on limited areas. Manchu is the most common variety. The chief use of this crop is for hay and silage. When grown for beans the average yield in 1931 was 10.9 bushels per acre.

Other crops grown in a limited way include wheat, sweet clover, buckwheat, flax, millet, rape, Sudan grass, sorghum, milo maize, pop corn, sweet corn, cabbage, watermelon, pumpkin and root-forage crops. Wheat is grown chiefly as a cash crop, both the winter and spring varieties being used. Spring wheat usually slightly outyields winter wheat. Sweet clover is used mainly for soil improvement, but it also provides hay and pasturage and in some cases is used for seed. Buckwheat and flax are usually planted as substitute crops on small areas where other crops have failed. The seed produced is marketed. Millet is grown on small areas as a short-season hay crop. Rape is sown with the corn or in small patches alone for forage. Sudan grass, sorghum and milo maize are grown for forage and fodder crops. Some sorghum is used for sirup. Pop corn, chiefly the Japanese Hulless variety, is grown on small areas for the local markets.

Sweet corn is grown largely in the vicinity of Clarksville, Ackley and Waverly for canning purposes. Evergreen and early Crosley are the popular varieties. Cabbage and watermelons are grown as truck crops. Some pumpkins are grown in the cornfields and root-forage crops, such as rutabagas, stock carrots and mangels are grown on small areas for forage.

There is little attention paid to orcharding. Apples are the most common tree fruit, and some grapes, plums, pears and cherries are grown. The Oldenburg, Wealthy, Sweet June, Wolf River, Yellow Transparent and Snow are the favorite varieties of apples. Concord is the common variety of grapes. Patches of small fruits, mainly strawberries, blackberries and raspberries are found on many farms. Most of the fruit is used to supply the home demands, but some is sold on the local markets.

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THE LIVESTOCK INDUSTRY IN BUTLER COUNTY

The livestock industry in the county includes the raising and feeding of hogs, cattle and sheep and dairying.

Pork production is the most important of the livestock enterprises. Most of the herds are composed of grade animals. The most popular breeds are Duroc Jersey, Poland China, Spotted Poland China and Chester White. Most of the hogs sold are shipped directly to Chicago, but large numbers are trucked to the Mason City and Waterloo packing houses.

Dairying is a side line on most farms, but in some cases it is the chief farm enterprise. The Holstein is the most popular dairy breed. There are some Guernsey, Jersey, Brown Swiss and Ayrshire herds. Dairy products provide a large part of the income on many farms.

The beef cattle marketed are farm-raised or native livestock purchased locally. Some cattle are shipped in from Sioux City or the Dakotas for winter fattening. Most of the beef cattle are grades. The Hereford is the most popular breed, and Angus and Shorthorn rank next. A few farmers specialize in purebred stock.

Sheep are raised on many farms. The average flock is 17 head. Considerable wool is clipped and sold. Some feeder sheep are purchased on the Sioux City and Omaha markets to be fed for short periods. Most of the sheep are of the Shropshire breed, but there are a few Oxfords. Little attention is paid to raising purebred sheep.

There is some raising of horses, chiefly to supply the local demand. The Belgian and Percheron breeds are the most popular. The work animals consist of good draft type horses and a few mules.

Poultry products add materially to the income on most farms. Some poultry are kept on practically all farms. Many of the fowls raised and eggs produced are marketed. Poultry production is coming to be of considerable importance and is receiving more attention as a profitable farm enterprise. In addition to chickens there are a few flocks of turkeys, geese and ducks.

THE FERTILITY IN BUTLER COUNTY SOILS

Much of the farm land in Butler County produces satisfactory crop yields, but frequently larger crops might be secured if better methods of soil management were followed. In some of the areas where the land is not properly drained, the installation of tile is the first treatment required to insure the production of satisfactory crops. The Clyde and Floyd soils on the drift uplands, the Bremer and the Fargo soils on the terraces, and the Wabash and Lamoure types on the bottomlands are likely to need tiling. In occasional areas of some of the other soils the drainage is not entirely adequate.

The soils of the county are all acid in reaction and therefore in need of lime in order to provide the best conditions for the growth of general farm crops and particularly legumes, such as sweet clover and alfalfa. The soils should all be tested for acidity and need of lime once in every 4 years, just prior to seeding the legume crop of the rotation. The lime shown to be necessary according to the test should be applied to insure the best growth of the legume. The succeeding grain crops will also be benefited by the lime and by the greater legume residues which are secured as a result of the liming.

On all the soils, organic matter and nitrogen must be added regularly if the supply is to be kept up. The light-colored, sandy soils are particularly deficient now and must be supplied with these constituents more often and in larger amounts if crop production is to be satisfactory. Farm manure is the most valuable fertilizing material for building up and maintaining the organic matter and nitrogen in soils. It brings about large increases in crop yields not only on the poorer soils, but also on the better, richer types. The turning under of crop residues also aids materially in keeping the soils well supplied with organic matter. Legumes used as green manures provide a very desirable supplement to farm manure and crop residues. When well inoculated, leguminous crops take a large part of their nitrogen from the atmosphere, and they serve, therefore, as nitrogenous fertilizers supplying nitrogen to the land along with the valuable organic matter.

There is no large supply of phosphorus in any of the soils, and in most cases the content is too small for the best crop yields. The use of phosphorus fertilizers is necessary on most of the land now and will be worth while in all cases in the very near future. The tests which have been made by farmers and the experiments which have been carried out on many of the soil types occurring in the county show the profit which may be secured by the application of superphosphate or rock phosphate to these soils, now.

Complete commercial fertilizers may be used in some cases with large profit, especially when truck crops are grown, but their general use for farm crops cannot be recommended. Ordinarily the phosphorus fertilizers will give quite as large increases and hence greater profit.

The addition of commercial nitrogenous fertilizers is not generally recommended for Butler county. Nitrogen may be more cheaply and quite as satisfactorily supplied by the turning under of legumes as green manures.

Commercial potassium fertilizers may prove profitable in some cases, especially for truck crops, but their general use cannot be recommended. Tests of such materials should always be carried out on small areas before an extensive application is made.

The injurious effects of erosion are shown in some areas in the county, especially on the Carrington, Dickinson, Lindley and Tama soils. It is very necessary that means be taken to prevent or control the washing away of the surface soil on these upland soils. In a later section of this report, methods which may be employed for various conditions are suggested.

THE GEOLOGY OF BUTLER COUNTY

The deposits of glacial till, made during the glacial age have covered the native bedrock so completely that the soil conditions in the county are little affected by the character of these underlying rocks. Only in the case of the Dodgeville and Millsdale soils is there any influence from the bedrock. In both these cases the soils rest upon limerock, which usually appears within the 3-foot section. None of the other soil types are influenced in any way by the native rocks.

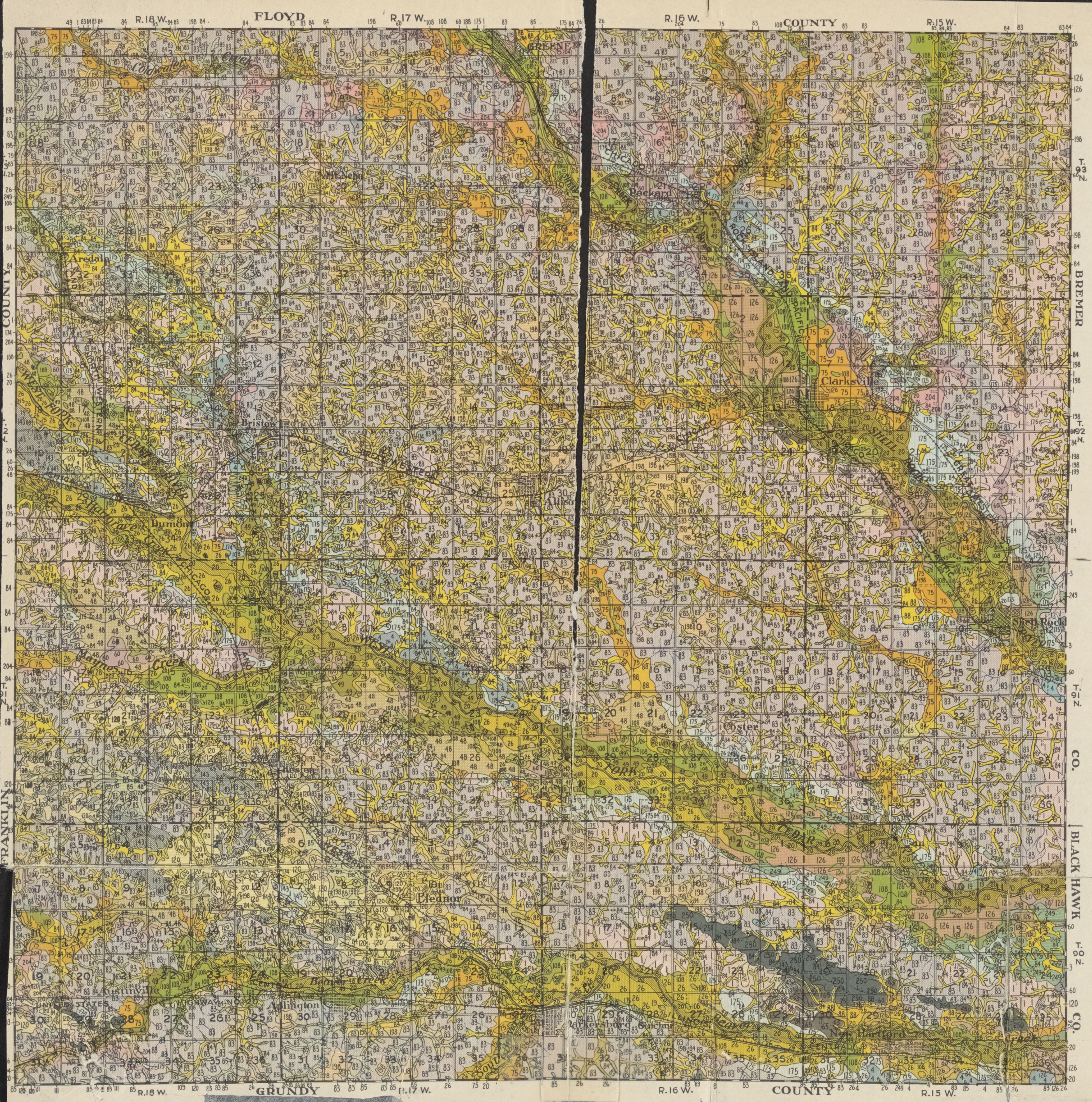
During the glacial age at least three great ice sheets swept across the county, leaving behind deposits of glacial debris or drift. The first, the Pre-Kansan, consisted of a greenish-blue or grayish-blue clay, containing gravel and boulders. None of the soils are formed from this early deposit, and hence it has little significance.

The Kansan glaciation was the second which covered the county. It left a deposit varying in depth from a few feet to 100 or more. This consisted of a blue clay containing many boulders. Upon oxidation the surface material changed to a reddish-brown, overlying a yellow boulder clay, grading into the unoxidized blue clay below. None of the soils in the county are derived entirely from this Kansan deposit, but in some places, erosion has occurred extensively and later deposits have been largely removed, exposing the older Kansan till in the 3-foot soil section. The soils of the Lindley series are thus formed, the subsoils being composed of Kansan till.

The Iowan glaciation, the third, covered the entire county, leaving behind a deposit of till, varying from 10 to 20 feet in thickness. This Iowan drift is a yellow clay filled with boulders, sand and much gravel. The soils of the county are derived mainly from this drift, the original material having been much weathered at the surface and made darker in color through the accumulation of organic matter. The surface soils are now mostly dark grayish-brown in color. The soils of the Carrington, Clyde, Floyd, Dickinson, Dodgeville series and the surface of the Lindley series are of Iowan drift origin.

Later, in geological ages, at a time when climatic conditions were quite different from those occurring at present, areas of silty material known as loess, were deposited by the wind. The material was carried over from the extensive loessial deposits to the east and south. Only small areas of these loess deposits are found, chiefly in the southern townships. The largest areas occur in the southwestern part of the county. Originally the loess was a yellowish, fine-grained silty material. With weathering and the accumulation of organic matter, it has taken on a darker color, becoming a dark grayish-brown in the surface soil, on the more extensive deeper areas. Erosion has occurred to some extent, and the loess has become much thinner than the original deposit. The depth of the loess is now extremely variable, due both to erosion and perhaps a lack of uniformity in the depth of the original deposit. The soils of the Tama and Fayette series are derived from the loessial material.

Somewhat extensive areas of terraces have been formed along the various streams in the county. They are made up of soils of upland drift origin which have been carried down by the streams and deposited on the stream banks, later being raised above overflow.



SOIL MAP OF BUTLER COUNTY, IOWA

Thomas D. Rice, Inspector, District Three. Soils Surveyed by J. Ambrose Elwell of the Iowa Agricultural Experiment Station and E. N. Poulson of the U. S. Department of Agriculture

U. S. DEPT. OF AGRICULTURE, BUREAU OF CHEMISTRY AND SOILS
Henry G. Knight, Chief. A. G. McCALL, Chief, Soil Investigations
Curtis F. Marbut, in charge Soil Survey

IOWA AGRICULTURAL EXPERIMENT STATION
R. M. Hughes, Acting Director P. E. Brown, in charge Soil Survey

AMERICAN LITHO. & PRINTING CO., DES MOINES, IOWA

SCALE: 1 INCH TO 2½ MILES

LEGEND

Drift Soils

- 83 Carrington silt loam
- 84 Clyde silt loam
- 1 Carrington loam
- 198 Floyd silt loam
- 175 Dickinson fine sandy loam
- 204 Dodgeville silt loam
- 85 Clyde silty clay loam
- 249 Dickinson loamy fine sand
- 4 Carrington fine sandy loam
- 199 Dickinson sandy loam
- 223 Dodgeville loam
- 65 Lindley loam
- 174 Dickinson loam
- 3 Carrington sandy loam

Loess Soils

- 120 Tama silt loam
- 143 Tama silt loam (shallow phase)
- 250 Fayette very fine sandy loam

Terrace Soils

- 108 O'Neill loam
- 75 Waukesha silt loam
- 126 O'Neill sandy loam
- 60 Waukesha loam
- 88 Bremer silt loam
- 109 Fargo silty clay loam
- 188 Millsdale loam

Swamp and Bottomland Soils

- 26 Wabash silt loam
- 20 Meadow
- 48 Wabash silty clay loam
- 49 Wabash loam
- 19 Cass sandy loam
- 111 Lamoure silty clay loam
- 21 Muck and Peat

The O'Neill, Waukesha and Millsdale soils occur on the higher terraces while the Bremer and Fargo soils are on low terraces or in depressed areas. The bottomland soils are likewise mainly of drift origin. They are subject to overflow. These soils are classified in the Wabash, Cass and Lamoure series. There are also areas of muck and peat and of meadow, the latter representing land which is so variable and so changing from stream floods that it cannot be classified in any soil series.

PHYSIOGRAPHY AND DRAINAGE

In topography, the land in Butler County is undulating to almost level. It is a characteristic drift plain topography. The slopes from the uplands to the alluvial land along the streams are generally very gradual. The uplands between the streams are smooth to level or undulating. The streams crossing the county are bordered by bottomlands varying from ½ to 2 miles in width. In the southwestern part of the county and along the northern border, the land

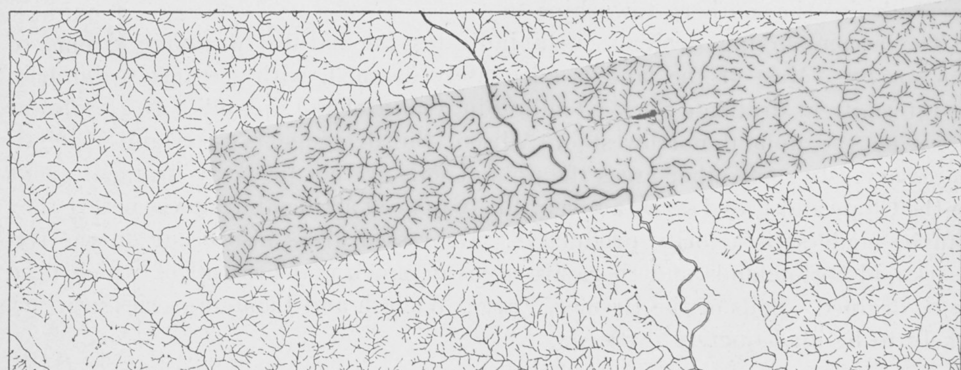


Fig. 2. Map showing natural drainage system of Butler County.

is rougher and the streams have carved deeper channels. From the center of Albion Township and eastward through Beaver Township there is a belt about 3 miles wide, where the land is sharply rolling with hills, ridges and deep valleys. From near the center of Monroe Township and extending to the northwest for several miles, there is a series of low hills which have been called pahas. Another series of these hills occurs west of Kelsey, and small areas, very similar in character, are found throughout the county. The general slope of the land is to the south and east, the direction in which the streams flow.

The drainage of the county is brought about by the three main streams, tributaries of the Cedar River, which flow across the county from northwest to southeast, and are well supplied with small tributary streams. The Shellrock River with its tributaries, Coldwater Creek, Flood Creek and numerous smaller streams, drains the northern and northeastern townships. The West Fork Cedar River with its tributaries, Hartgrave Creek, Maynes Creek and many minor streams, drains the central and southeastern townships. Beaver Creek with its tributaries drains the southern townships.

The accompanying drainage map indicates the natural drainage system of the county. Most of the land is adequately drained, with streams, tributaries or intermittent drainage lines extending into most of the uplands. In the flatter areas on the upland northwest of Allison, the drainage is poor and tiling is necessary. In some other areas the upland soils are not properly drained. Soils in the Clyde and Floyd series are very likely to need artificial drainage before they can be made satisfactorily productive. Depressed areas also occur on the terraces and bottomlands and there are areas of muck and peat all of which need to be drained. Soils of the Bremer, Fargo, Wabash and Lamoure series are very likely to be inadequately drained.

THE SOILS OF BUTLER COUNTY

The soils of Butler County are grouped into four classes on the basis of their origin and location—drift, loess, terrace and swamp and bottomland soils. Drift soils are formed from glacial material left behind on the surface of the land when the glaciers retreated. They are variable in composition and contain boulders, pebbles and coarse sand or gravel. Loess soils are fine dust-like deposits made by the wind at some time when climatic conditions were quite different from the present. Terrace soils are old bottomlands which have been raised above overflow by a deepening of the river channel or a decrease in the volume of the streams which deposited them, or both. Swamp and bottomland soils occur in low, poorly drained areas or along streams where they are subject to more or less frequent overflow. The occurrence of these soils in the county is shown in table II.

TABLE II. AREAS OF DIFFERENT GROUPS OF SOILS IN BUTLER COUNTY

Soil Group	Acres	Percent of total area of county
Drift soils	266,752	71.6
Loess soils	12,288	3.3
Terrace soils	48,064	12.9
Swamp and bottomland soils	44,736	12.2
Total	371,840	....

The drift soils cover almost three-fourths of the total area of the county—71.6 percent. Loess soils are of limited occurrence, covering only 3.3 percent of the county. Terrace soils cover 12.9 percent, and swamp and bottomland soils 12.2 percent of the total area.

There are 28 soil types, and these with the shallow phase Tama silt loam and the meadow and muck and peat make a total of 31 separate soil areas. There are 14 drift soils, 3 loess soils, 7 terrace types and 7 areas of swamp and bottomland soils. The areas of the different soils are shown in table III.

The Carrington silt loam is by far the most extensively developed type, and the largest drift soil. It covers 31 percent of the county. The Clyde silt loam is the second largest type, covering 16 percent of the total area. The Carrington loam is third, covering 7.6 percent and the Floyd silt loam fourth, covering 6.6 percent of the county. The Dickinson fine sandy loam is the fifth drift soil, but the seventh type in the county, covering 4.1 percent of the total area. The Dodgeville silt loam, the Clyde silty clay loam and the Dickinson loamy fine sand cover 1.6, 1.5 and 1.1 percent of the county, respectively. The remaining drift soils of the Carrington, Dickinson, Dodgeville and Lindley series each cover less than 1 percent of the total area.

The Tama silt loam, the larger of the loess types, with the shallow phase which is much smaller in area, covers only 2.7 percent of the county. The Fayette very fine sandy loam covers less than 1 percent of the total area.

The O'Neill loam is the largest of the terrace soils and the sixth largest type in the county, covering 4.3 percent of the total area. The Waukesha silt loam is the second terrace soil, covering 3.3 percent of the county. The O'Neill sandy loam is third, covering 2.6 percent and the Waukesha loam is fourth, covering

TABLE III. AREAS OF DIFFERENT SOIL TYPES IN BUTLER COUNTY

Soil No.	Soil Type	Acres	Percent of total area of county
	DRIFT SOILS		
83	Carrington silt loam	115,392	31.0
84	Clyde silt loam	59,712	16.0
1	Carrington loam	28,352	7.6
198	Floyd silt loam	24,448	6.6
175	Dickinson fine sandy loam	15,424	4.1
204	Dodgeville silt loam	6,080	1.6
85	Clyde silty clay loam	5,632	1.5
249	Dickinson loamy fine sand	3,968	1.1
4	Carrington fine sandy loam	3,200	0.8
199	Dickinson sandy loam	1,728	0.5
223	Dodgeville loam	1,088	0.3
65	Lindley loam	960	0.2
174	Dickinson loam	640	0.2
3	Carrington sandy loam	128	0.1
	LOESS SOILS		
120	Tama silt loam	6,784	2.7
143	Tama silt loam (shallow phase)	3,328	
250	Fayette very fine sandy loam	2,176	0.6
	TERRACE SOILS		
108	O'Neill loam	16,064	4.3
75	Waukesha silt loam	12,352	3.3
126	O'Neill sandy loam	9,664	2.6
60	Waukesha loam	5,952	1.6
88	Bremer silt loam	3,584	0.9
109	Fargo silty clay loam	256	0.1
188	Millsdale loam	192	0.1
	SWAMP AND BOTTOMLAND SOILS		
26	Wabash silt loam	17,792	4.8
20	Meadow	11,776	3.2
48	Wabash silty clay loam	8,448	2.3
49	Wabash loam	5,696	1.5
19	Cass sandy loam	832	0.2
111	Lamoure silty clay loam	64	0.1
21	Muck and peat	128	0.1
	Total	371,840	....

1.6 percent of the total area. The other terrace types of the Bremer, Fargo and Millsdale series each cover less than 1 percent of the county.

The Wabash silt loam is the largest of the bottomland soils and the fifth largest soil in the county, covering 4.8 percent of the total area. The area of Meadow is second, amounting to 3.2 percent of the county. The Wabash silty clay loam is third, covering 2.3 percent and the Wabash loam fourth, covering 1.5 percent of the total area. The remaining areas of Cass sandy loam, Lamoure silty clay loam and muck and peat each cover less than 1 percent of the county.

Some relationships are evident between the topographic features of the upland soils and the types mapped. Thus, on the drift uplands the Clyde soils occur in flat to depressed areas. The Floyd soils are relatively level to slightly undulating. The Carrington and Dickinson types are undulating to rolling, the Dodgeville soils undulating and the Lindley soils strongly rolling to rough in topography. On the loessial uplands the Tama soils are undulating to rolling and the Fayette types are similar in topography. Very little topography is developed on the terraces except that the O'Neill, Waukesha and Millsdale soils are higher and better developed, the Bremer types are lower and poorly developed, while the Fargo soils occur in depressions. The bottomlands show no topographic features.

THE FERTILITY IN BUTLER COUNTY SOILS

Samples were taken for analysis from each of the soil types, except the Carrington sandy loam, the shallow phase of the Tama silt loam, the Lamoure silty clay loam, and the areas of meadow and muck and peat. These soils were not sampled because of very limited occurrence and unimportance agriculturally and, in the case of the meadow and areas of muck and peat, the great variability of the material. The soils developed most extensively were sampled in triplicate, but only one sample was taken of each of the minor soil types. The samplings were made with the utmost care, avoiding any apparently abnormal conditions or any areas unrepresentative of the soil type, because of some previous treatment.

Samples were taken at three depths, 0 to 6⅔ inches, 6⅔ to 20 inches and 20 to 40 inches, representing the surface soil, subsurface soil and subsoil, respectively. Analyses were made for total phosphorus, total nitrogen, total organic carbon, inorganic carbon and limestone requirement. The official methods were followed in the phosphorus, nitrogen and carbon determinations, and the Truog qualitative test was used in the limestone requirement determinations. The results given in the tables are the averages for the results of duplicate determinations on all samples of each type, and they are, therefore, the averages of two or six determinations.

The Surface Soils

The results of the analyses of the surface soils are shown in table IV. They are calculated on the basis of 2 million pounds of surface soil per acre. The phosphorus content of the soils varies considerably, ranging from 740 pounds per acre in the Carrington fine sandy loam up to 2,424 pounds per acre in the Clyde silt loam. No apparent relationship occurs between the phosphorus supply in the soils and the different groups of soils except that the terrace and bottomland soils are a little better supplied, on the average, with the element than the upland types.

The supply of phosphorus in the soil seems to bear some relation to the series in which the type is mapped; thus on the drift uplands, the Clyde soils are much the richest in phosphorus, the Carrington types are generally lower than the Clyde but richer than the other soils, except in the case of the Carrington fine sandy loam which is the lowest of all the drift upland soils. The Floyd soils are richer than the Dickinson, Dodgeville and Lindley types and the Dickinson and Lindley are the poorest in phosphorus, the Lindley being poorer than the Dickinson soils. On the loessial uplands the Tama silt loam is much higher in phosphorus than the Fayette very fine sandy loam. On the terraces the Bremer soils are the richest in phosphorus, the Waukesha and Fargo types are second, the Millsdale soils third and the O'Neill types are the lowest. On the bottomlands the Wabash soils are much better supplied with the element than the Cass soil.

Those characteristics which serve to distinguish the various soil series evidently have some effect on the phosphorus supply. Thus, the color of the soil, the topography, the character of the subsoil and the origin and previous history of the development of the soils influence the content of the element. Those types which

TABLE IV. PLANT FOOD IN BUTLER COUNTY, IOWA, SOILS
Pounds per acre of 2 million pounds of surface soil (0–6⅔")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
83	Carrington silt loam	1,801	4,493	58,182	.....	7,000
84	Clyde silt loam	2,424	13,400	129,892	.....	.....
1	Carrington loam	1,180	4,067	47,440	.....	6,000
198	Floyd silt loam	1,643	8,480	93,399	.....	2,000
175	Dickinson fine sandy loam	848	1,840	23,615	.....	3,000
204	Dodgeville silt loam	1,252	3,440	43,359	.....	2,000
85	Clyde silty clay loam	1,952	9,080	87,539	.....	.....
249	Dickinson loamy fine sand	875	800	25,606	.....	6,000
4	Carrington fine sandy loam	740	2,880	34,851	.....	7,000
199	Dickinson sandy loam	983	1,760	31,469	.....	4,000
223	Dodgeville loam	862	3,080	37,496	.....	6,000
65	Lindley loam	821	2,560	33,323	.....	3,000
174	Dickinson loam	1,118	1,920	24,188	.....	6,000
	LOESS SOILS					
120	Tama silt loam	1,347	10,040	64,411	.....	5,000
250	Fayette very fine sandy loam	794	2,200	28,824	.....	3,000
	TERRACE SOILS					
108	O'Neill loam	1,144	4,200	49,058	.....	4,000
75	Waukesha silt loam	1,778	7,160	76,765	.....	6,000
126	O'Neill sandy loam	767	840	13,771	.....	6,000
60	Waukesha loam	1,198	3,520	42,513	.....	6,000
88	Bremer silt loam	1,938	6,680	79,680	.....	3,000
109	Fargo silty clay loam	1,697	5,520	65,036	75,540	.....
188	Millsdale loam	1,441	3,120	39,459	.....	2,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	1,198	7,120	77,310	.....	3,000
48	Wabash silty clay loam	1,818	6,800	86,418	.....	2,000
49	Wabash loam	1,198	3,280	33,323	.....	2,000
19	Cass sandy loam	848	3,080	26,015	.....	6,000

are dark in color, level in topography and have heavy subsoils, such as the Clyde, Bremer and Wabash soils are richer in phosphorus than the lighter colored soils, which are more rolling in topography and have coarser textured subsoils, such as the Lindley, Dickinson, O'Neill and Cass soils.

The influence of the texture of the soil on the phosphorus supply is shown in some cases. The Clyde silt loam is a little higher than the silty clay loam, which is contrary to the usual results, the silty clay loam ordinarily being the richer. The Carrington silt loam is higher than the loam and the loam is richer than the fine sandy loam. The Dickinson loam is richer than the sandy loam which, in turn, is richer than the loamy fine sand or fine sandy loam. There is little difference in the phosphorus in the two latter types. The Dodgeville silt loam is richer than the Dodgeville loam. On the terraces the Waukesha silt loam is higher than the loam and the O'Neill loam is richer than the sandy loam. On the bottomlands the Wabash silty clay loam is higher than the silt loam or loam. There is no difference in the latter types, although the silt loam is usually richer than the loam. It appears, therefore, that silty clay loams are higher than silt loams which, in turn, are generally richer than loams, and loams are better supplied than sandy loams.

The analyses of the soils indicate that the phosphorus content is generally low, and hence it is evident that phosphorus will soon become a limiting factor in crop growth. Phosphorus fertilizers will certainly be needed on these soils in the near future and in many cases could undoubtedly be applied with profit now.

In nitrogen content, the soils range from 800 pounds per acre in the Dickinson loamy fine sand up to 13,400 pounds per acre in the Clyde silt loam. No relationship appears between the various soil groups and the nitrogen content of the soils, although the bottomland types are on the average a little better supplied.

The differences in color, topography, subsoil, character and origin, which serve largely as the bases for series differentiation, are apparently reflected in the nitrogen supply. Thus, on the drift uplands, the Clyde soils which are the darkest in color, the most level in topography and which have the heaviest subsoils are the richest in nitrogen. The Floyd soils are second, the Carrington third, then the Dodgeville types and the Lindley and Dickinson soils are the lowest. On the loessial uplands the Tama silt loam is much richer than the Fayette soil. On the terraces the Waukesha, Bremer and Fargo soils are the richest, while the O'Neill types are the lowest. On the bottomlands the Wabash soils are richer than the Cass.

Differences in texture of the soils also affect the nitrogen content. Thus, the Carrington silt loam is richer than the loam which, in turn, is better supplied than the fine sandy loam. The Dickinson loam is slightly higher than the sandy loam or fine sandy loam. The Dickinson loamy fine sand is the lowest of the Dickinson soils. The Dodgeville silt loam is higher than the loam. The Clyde silt loam is higher than the silty clay loam which is contrary to the usual results, due probably to some abnormality in the particular sample. On the terraces the Waukesha silt loam is much higher than the loam, and the O'Neill loam is richer than the fine sandy loam. On the bottomlands the Wabash silt loam is higher than the loam, but it is also higher than the silty clay loam which is not usual. Ordinarily, silty clay loams are higher than silt loams which are better supplied than loams, and loams are richer than the sandy textured types.

Some of the soils are fairly well supplied with nitrogen, but others are not rich in this element. These soils need nitrogen fertilization now, and all the types must be treated with fertilizing materials adding nitrogen at regular intervals if the supply is to be kept up. Farm manure, crop residues and legumes as green manures are the cheapest and best means of supplying nitrogen.

The organic carbon content of the soils varies in much the same way as the nitrogen content. The amount present ranges from 13,771 pounds per acre in the O'Neill sandy loam up to 129,882 pounds per acre in the Clyde silt loam.

Again, little apparent relationship between the organic carbon content and the soil groups is shown, although the bottomland types are a little richer, on the average.

The characteristics which serve to distinguish the soil series affect the content of organic carbon. The color, topography and subsoil character, all seem to be related directly to the organic carbon supply. Thus, the Clyde and Floyd soils on the drift uplands are the richest, and they are the darkest in color, more level in topography and have the heaviest subsoils. The Carrington soils are richer than the Dodgeville, Lindley and Dickinson types. The latter are the lowest, due mainly to their coarse textured subsoils. The Waukesha, Bremer and Fargo soils are the richest among the terrace soils, and they are the darkest in color and have heavy subsoils. The O'Neill types are the poorest, due to their sandy subsoils. The Cass soils are lower than the Wabash types because of their coarse textured subsoils.

The texture of the soils in the different series is shown to have some effect on the organic carbon content. The Carrington silt loam is higher than the loam which is higher than the fine sandy loam. The Clyde silt loam is again higher than the silty clay loam, as in the case of nitrogen, contrary to the usual results. The Dodgeville silt loam is higher than the loam. The Dickinson sandy loam is higher than the fine sandy loam or loamy fine sand, but it is also higher than the loam which is contrary to the usual results. The Waukesha silt loam is much richer in organic carbon than the loam, and the O'Neill loam is higher than the sandy loam of the same series. The Wabash silty clay loam is higher than the silt loam which is much richer in organic carbon than the Wabash loam. It appears that in general, silty clay loams are higher than silt loams in organic carbon; silt loams are richer than loams which, in turn, are richer than the sandy types.

Many of the soils in the county are well supplied with organic matter, as is evidenced by their dark color, but in some cases the content is too low for the most satisfactory growth of crops. In the lighter colored sandy types, it is very

TABLE V. PLANT FOOD IN BUTLER COUNTY, IOWA, SOILS
Pounds per acre of 4 million pounds of subsurface soil (6⅔"–20")

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
83	Carrington silt loam........	2,101	6,307	56,421	.....	7,000
84	Clyde silt loam............	3,958	17,520	192,968	.....	.....
1	Carrington loam	1,822	4,693	46,876	.....	6,000
198	Floyd silt loam	2,640	10,160	118,869	.....	.....
175	Dickinson fine sandy loam...	1,778	2,880	46,795	.....	5,000
204	Dodgeville silt loam........	1,588	3,840	51,103	.....	2,000
85	Clyde silty clay loam.......	3,070	7,360	86,083	.....	.....
249	Dickinson loamy fine sand...	1,212	880	15,216	.....	6,000
4	Carrington fine sandy loam..	1,588	4,400	52,194	.....	7,000
199	Dickinson sandy loam.......	1,320	2,560	38,996	.....	6,000
223	Dodgeville loam	1,480	4,080	52,849	.....	7,000
65	Lindley loam	1,293	1,040	21,543	.....	4,000
174	Dickinson loam	1,938	1,920	30,706	.....	7,000
	LOESS SOILS					
120	Tama silt loam	2,316	6,240	65,448	.....	5,000
250	Fayette very fine sandy loam.	1,724	2,000	25,033	.....	4,000
	TERRACE SOILS					
108	O'Neill loam	1,804	4,800	53,285	.....	5,000
75	Waukesha silt loam	3,204	10,320	122,442	.....	6,000
126	O'Neill sandy loam.........	1,293	1,680	35,996	.....	4,000
60	Waukesha loam	2,396	7,280	82,246	.....	6,000
88	Bremer silt loam..........	3,070	10,160	140,033	.....	3,000
109	Fargo silty clay loam......	4,040	19,360	57,920	137,520	.....
188	Millsdale loam	3,098	1,520	80,828	.....	2,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam...........	2,828	9,440	110,279	.....	5,000
48	Wabash silty clay loam......	3,368	11,360	143,440	.....	2,000
49	Wabash loam	2,208	3,760	52,031	.....	2,000
19	Cass sandy loam............	2,020	3,360	49,685	.....	4,000

important that some fertilizing material supplying organic matter be added. The use of farm manure and the turning under of legumes as green manures are essential for increasing the organic matter content in the lighter-colored soils and making them more productive.

None of the soils, except the Fargo silty clay loam on the terraces, contain any inorganic carbon. All except this one type are, therefore, acid and in need of lime. The lime requirements of the various types, as shown in table IV, are indicative only of the needs of the soils in the field. There is such a wide difference in the acidity or lime requirement in various soils and even among soils of the same type from different areas, that lime should be applied only after the particular area has been tested and the exact needs of the soil determined.

The Subsurface Soils and Subsoils

The results of the analyses of the subsurface soils and subsoils are given in tables V and VI. They are calculated on the basis of 4 million pounds of subsurface soil and 6 million pounds of subsoil per acre.

The analyses of the surface soils undoubtedly show accurately the needs of the different soil types, and it is hardly necessary to discuss in detail the analyses of the lower soil layers. There are no large amounts of any of the essential plant food constituents in the subsurface or subsoil layers, and deficiences in the surface

TABLE VI. PLANT FOOD IN BUTLER COUNTY, IOWA, SOILS
Pounds per acre of 6 million pounds of subsoil (20″–40″)

Soil No.	Soil Type	Total phosphorus	Total nitrogen	Total organic carbon	Total inorganic carbon	Limestone requirement
	DRIFT SOILS					
83	Carrington silt loam	2,019	7,680	51,012	.....	7,000
84	Clyde silt loam	3,354	3,120	47,547	.....	.....
1	Carrington loam	2,174	2,480	38,878	.....	6,000
198	Floyd silt loam	2,787	1,800	25,868	.....	.....
175	Dickinson fine sandy loam	2,139	2,760	43,522	.....	7,000
204	Dodgeville silt loam	2,463	1,560	23,970	.....	2,000
85	Clyde silty clay loam	3,717	3,240	47,487	.....	.....
249	Dickinson loamy fine sand	1,657	1,200	17,589	.....	4,000
4	Carrington fine sandy loam	2,100	3,000	45,649	.....	5,000
199	Dickinson sandy loam	1,980	1,680	23,643	.....	4,000
223	Dodgeville loam	1,333	2,280	31,006	.....	7,000
65	Lindley loam	1,857	10,680	14,725	.....	7,000
174	Dickinson loam	3,474	600	14,153	.....	4,000
	LOESS SOILS					
120	Tama silt loam	2,907	2,640	33,542	.....	5,000
250	Fayette very fine sandy loam	3,231	1,440	17,343	.....	4,000
	TERRACE SOILS					
108	O'Neill loam	2,301	960	14,959	.....	3,000
75	Waukesha silt loam	2,505	6,840	83,855	.....	6,000
126	O'Neill sandy loam	1,776	1,080	14,643	.....	3,000
60	Waukesha loam	2,586	4,920	57,676	.....	5,000
88	Bremer silt loam	2,463	3,960	55,467	.....	2,000
109	Fargo silty clay loam	3,717	3,720	54,721	188,091	.....
188	Millsdale loam	2,424	1,320	32,396	.....	3,000
	SWAMP AND BOTTOMLAND SOILS					
26	Wabash silt loam	2,667	4,680	65,202	.....	4,000
48	Wabash silty clay loam	2,826	11,880	181,126	.....	3,000
49	Wabash loam	2,586	7,920	107,007	.....	2,000
19	Cass sandy loam	1,454	600	9,980	.....	2,000

soil will not, therefore, be supplied from below. In general, the plant food content is lower in the deeper layers of soil, and the needs are actually greater than the surface soil analyses indicate.

The needs of the various soils, as previously suggested, are thus borne out by these analyses. The supply of phosphorus in the soils is certainly low, and it is evident that phosphorus fertilizers will be needed in the very near future and may be of large value now. The content of organic matter and nitrogen is low in some cases, and some fertilizing materials supplying these constituents must be added. For the maintenance of permanent fertility, all the soils must receive regular applications of fertilizing materials such as farm manure or leguminous green manures if the supply of organic matter and nitrogen is to be kept up. All the soils except the Fargo silty clay loam are acid in reaction and in need of lime. If legumes, such as the clovers and alfalfa are to be grown and if the soils are to be kept fertile, all the soils except the Fargo must be tested and must receive lime as needed.

GREENHOUSE EXPERIMENTS

Two greenhouse experiments were carried out on soils from Butler County to secure some indications of the fertilizer needs of the soils and the value of various fertilizing materials. These tests were conducted on the Carrington silt loam and the Carrington loam, two of the more important soils.

The treatments tested in these experiments included the application of manure, limestone, superphosphate and muriate of potash. These materials were applied in amounts which are ordinarily used in the field and the results may, therefore, be considered to show fairly accurately the effects of similar treatments made to soils in the field. Manure was applied at the rate of 10 tons per acre, lime was added in sufficient amounts to neutralize the acidity of the soil, superphosphate was applied at the rate of 250 pounds per acre and muriate of potash was used at the rate of 50 pounds per acre. Wheat and clover were grown in the pots, the clover being seeded about 1 month after the wheat was up. In one case the wheat yield was not secured as the crop was injured in some of the pots.

The Results on the Carrington Silt Loam

The results of the experiment on the Carrington silt loam from Butler County are given in table VII.

TABLE VII. GREENHOUSE EXPERIMENT, CARRINGTON SILT LOAM, BUTLER COUNTY

Pot No.	Treatment	Weight of wheat grain in grams	Weight of clover in grams
1	Check	10.7	75.8
2	Manure	12.0	97.0
3	Manure+limestone	13.8	84.5
4	Superphosphate	10.8	78.9
5	Manure+superphosphate	13.3	83.8
6	Limestone+superphosphate	9.9	114.3
7	Manure+limestone+superphosphate	14.1	104.0
8	Manure+limestone+superphosphate+muriate of potash	12.7	94.5

Manure increased the yields of wheat and clover considerably, showing an especially large effect on the clover. Lime with manure increased the wheat yield but had no effect on the clover. Ordinarily a very definite effect would appear on the clover. Superphosphate alone had little effect on either crop. It had much less influence than manure alone. Manure and superphosphate increased the wheat yield over manure or superphosphate alone, but had less effect than manure alone on the clover. Limestone with superphosphate had no effect on the wheat, but brought about a large increase in the clover. Manure with limestone and superphosphate gave the greatest effect of any treatment on the wheat, but showed no greater effect than the limestone and superphosphate without manure on the clover. Muriate of potash with manure, limestone, and superphosphate had no effect on either crop.

The Results on Carrington Loam

The results secured in the test on the Carrington loam from Butler County are given in table VIII.

TABLE VIII. GREENHOUSE EXPERIMENT, CARRINGTON LOAM, BUTLER COUNTY

Pot No.	Treatment	Weight of wheat grain in grams*	Weight of clover in grams
1	Check	.....	22.1
2	Manure	.....	56.7
3	Manure+limestone	.....	53.5
4	Superphosphate	.....	36.3
5	Manure+superphosphate	.....	74.2
6	Limestone+superphosphate	.....	40.3
7	Manure+limestone+superphosphate	.....	62.0
8	Manure+limestone+superphosphate+muriate of potash	.....	54.9

* Wheat damaged by rats, no results.

Manure increased the clover yield to a very large extent; limestone with manure had no further effect, although in most cases limestone would show a large effect on legumes. Superphosphate alone had a beneficial influence on the crop, but less effect than manure alone. Manure with superphosphate gave a large increase in the clover, a much greater effect than that shown by the manure alone. Limestone with superphosphate had a greater effect than superphosphate alone. The treatment with manure, limestone and superphosphate had no greater effect than manure and superphosphate without the lime and, in fact, there was a smaller increase from the treatment probably due to the variations in crop growth on the pots in the greenhouse. Muriate of potash with manure, limestone and superphosphate had no effect on the clover.

FIELD EXPERIMENTS

No field experiments have been carried out in this county, but tests are under way in adjacent counties on the same soil types as those occurring extensively in Butler County, and the results secured on some of these fields will be given here. The data obtained in the experiments on the Carrington silt loam on the Osage Field, No. II, in Mitchell County, on the Calamus Field in Clinton County, on the Low Moor Field in Clinton County, and on the Springville Field in Linn County, and on the Carrington loam on the Waverly Field, No. II, Series I and II in Bremer County, on the Eldora Field, Series 200 in Hardin County, on the Jesup Field in Black Hawk County, and on the Independence Field in Buchanan County will be given here. The results may be regarded as definitely applicable to Butler County.

These field experiments are planned to determine the relative value of various soil treatments, and they are laid out on land which is representative of the individual soil types. They are permanently located by corner stakes and all precautions are taken in the application of fertilizers and in the harvesting of crops to be sure that the results secured are accurate. In these experiments, tests are included under both the livestock and grain systems of farming, manure being employed in the former and crop residues turned under in the soil in the latter.

Other fertilizing materials tested include limestone, rock phosphate, superphosphate, a complete commercial fertilizer and muriate of potash. Farm manure is applied at the rate of 8 tons per acre once in the 4-year rotation. Limestone is added in sufficient amounts to neutralize the acidity of the surface soil. The crop residue treatment consists of plowing under the cornstalks which have been cut with a disc or stalk cutter in the spring after having been winter-pastured. Sometimes the second crop of clover is plowed under, but usually it is used for seed, hay or pasture and only the residues are plowed down. Rock phosphate was added at the rate of 1 ton per acre once in 4 years until 1925, when the application was reduced to 1,000 pounds once in the 4-year rotation. Superphosphate (16 percent) was applied at the rate of 200 pounds per acre annually 3 years out of 4 in the 4-year rotation. It was not applied to the legume crop. Beginning in 1929 sufficient 20 percent superphosphate has been used to supply the same amount of phosphorus as previously employed.

The old standard 2-8-2 complete commercial fertilizer was applied at the rate of 300 pounds per acre annually until 1922, when the 2-12-2 brand was applied at the rate of 200 pounds per acre 3 years out of 4, thus supplying the same amount of phosphorus as that added in the superphosphate. In 1929 a change was made to a 2-12-6 complete fertilizer, applying the same amount as previously in order to supply an equivalent amount of phosphorus. Muriate of potash is applied at the rate of 25 pounds per acre 3 years out of 4 in the 4-year rotation.

The Osage Field

The results secured on the Carrington silt loam on the Osage Field II in Mitchell County are given in table IX. The application of manure increased the crop yields on this soil in practically all cases. In some seasons very large increases were noted as on the oats in 1920, the clover in 1921, the clover and timothy in 1925, the corn in 1926 and the barley in 1932. Limestone with manure appreciably increased the crop yields in all but three cases. No influence was shown on the corn in 1918 or 1922 nor on the oats in 1920, but in all other cases considerable gains were noted. The clover in 1921, the clover and timothy in 1925, and the clover in 1929 were benefited to a particularly large extent. Large increases were also secured on the corn in 1923 and 1927 and on the oats in 1928.

Rock phosphate with manure and limestone increased crop yields in practically all seasons. The largest effects were evidenced on the corn in 1922 and 1923 and on the barley in 1932. The increases from rock phosphate usually were not very large. Superphosphate with manure and lime showed somewhat larger effects than rock phosphate on the corn in 1918, 1919 and 1923, on the oats in

TABLE IX. FIELD EXPERIMENT, CARRINGTON SILT LOAM, MITCHELL COUNTY
OSAGE FIELD NO. II,* SERIES I

Plot No.	Treatment	1918 corn bu. per A. (1)	1919 corn bu. per A.	1920 oats bu. per A. (2)	1921 clover tons per A. (3)	1922 corn bu. per A. (4)	1923 corn bu. per A. (5)	1924 oats bu. per A. (6)	1925 clover and timothy T. per A. (7)	1926 corn bu. per A.	1927 corn bu. per A. (8)	1928 oats bu. per A.	1929 clover tons per A. (9)	1930 corn bu. per A.	1931 corn bu. per A. (10)	1932 barley bu. per A.
1	Check	46.5	55.8	34.6	1.09	58.8	42.3	72.4	0.97	37.3	25.9	60.1	1.47	54.6	26.0	24.2
2	Manure	52.8	60.0	60.3	1.55	68.0	50.8	71.0	1.25	51.4	26.6	69.2	1.40	74.6	22.5	32.3
3	Manure+limestone	52.8	70.0	56.3	1.98	68.0	64.1	82.8	1.64	56.0	41.4	82.8	1.94	76.3	24.8	34.3
4	Manure+limestone +rock phosphate	54.8	72.0	61.2	1.94	74.3	70.7	86.5	1.68	57.0	43.5	81.7	1.59	76.1	22.7	41.1
5	Manure+limestone +superphosphate	56.4	77.0	61.2	1.82	76.0	70.7	98.0	1.90	55.7	40.9	71.5	1.90	74.5	11.1	33.4
6	Manure+limestone +complete commercial fertilizer	44.5	79.0	67.3	1.63	72.3	70.2	102.9	1.92	60.8	38.8	72.6	1.66	75.0	12.0	37.9
7	Check	38.8	67.0	59.8	1.48	50.0	53.7	74.3	1.12	46.6	25.5	63.5	1.78	64.4	18.4	27.4
8	Crop residues	37.7	65.0	55.0	1.55	51.4	52.0	71.8	1.14	41.3	25.9	64.7	1.69	63.5	17.2	27.4
9	Crop residues+ limestone	39.4	74.0	50.3	1.55	58.3	65.2	81.6	1.63	52.0	38.0	68.1	1.83	67.0	18.0	28.4
10	Crop residues+ limestone+rock phosphate	47.4	75.0	61.8	1.55	57.7	64.4	90.3	1.94	52.5	25.6	66.9	2.07	64.0	14.5	28.6
11	Crop residues+ limestone+ superphosphate	44.2	73.0	59.8	1.44	62.3	64.9	78.4	2.07	51.2	35.9	76.0	1.95	60.5	10.7	31.8
12	Crop residues+ limestone+complete commercial fertilizer	48.8	78.0	67.3	1.79	65.5	69.9	87.1	1.55	50.9	37.3	66.9	1.77	65.2	10.9	32.3
13	Check	39.7	67.0	53.1	1.59	52.3	53.2	75.6	0.88	44.0	30.4	56.7	1.55	60.8	14.6	25.0

(1) Four tons limestone applied.
(2) Plot 1, low yield, oats down badly; 4 tons lime applied in September.
(3) Clover pastured heavily in spring.
(4) Corn down badly on checks and crop residue plots.
(5) Dry weather reduced yields.
(6) Poor stand on plot 11 due to pocket gophers.
(7) Clover mostly killed out in spring due to ice sheet; good stand of timothy.
(8) Plot 10 damaged by gophers.
(9) Plots damaged by fall and early spring pasturing.
(10) Hot, dry season; poor quality corn.
* The Osage Field was established in the fall of 1917 on the farm of Roy J. Fish, near Osage, in Mitchell County. It is located in the SW corner of the SW ¼ of Section 19, R. 16 W., Township 98 N.

1924 and on the clover in 1925 and 1929. In several cases, however, rock phosphate gave somewhat better results as shown on the clover in 1921, on the corn in 1926 and 1927, on the oats in 1928 and on the barley in 1932. The corn yield was abnormal on the entire field in 1931, owing to the drouth, but the superphosphate plot was more abnormal than the others. The complete commercial fertilizer with the manure and lime showed somewhat larger effects than superphosphate in a number of cases. In some cases, however, superphosphate gave superior results. In general, the differences between the two materials were not large.

The crop residues showed little influence on the crops grown in most seasons. Lime with the residues usually increased the crop yields, and in most seasons the increases were very pronounced. The clover in 1925 and in 1929 was benefited to a particularly large extent. Large increases were also noted on the corn in 1923, 1926 and 1927 and on the oats in 1924.

Rock phosphate with manure and limestone increased the yields of the various crops grown in most seasons. The largest beneficial effects of rock phosphate were evidenced on the clover and timothy in 1925 and on the clover in 1929. There was also a considerable increase on the oats in 1920 and 1924. The beneficial effects on the corn were generally small. Superphosphate with the crop residues and lime showed somewhat greater effects than rock phosphate in some seasons, particularly on the clover and timothy in 1925, on the corn in 1927, on the oats in 1928 and on the barley in 1932. In many cases, however, rock phosphate gave somewhat greater effects, but in general the differences were not very striking. The complete commercial fertilizer with the crop residues and limestone showed a greater effect on crop yields than superphosphate in most seasons. In some cases the differences were considerable, as for example, on the clover in 1921, but in general the complete commercial fertilizer did not give large increases.

The Calamus Field

The results secured on the Carrington silt loam on the Calamus Field in Clinton County are given in table X. Manure increased the crop yields in all but one season. Very large increases were secured with the wheat in 1915, the corn in 1916, 1920, 1921 and 1923, the oats in 1917, 1924 and 1928, and the clover in 1918, 1919 and 1925. Limestone alone had a beneficial effect on the crops grown in every season. The influence of lime was often greater than that of manure as, for example, on the clover in 1919 and 1929, on the corn in 1916, 1921, 1926, 1927, 1930 and 1931 and on the oats in 1924 and 1932, but in the other seasons manure alone had a greater effect or about the same influence. Manure and limestone together had a greater effect than either material alone in practically all cases. In some instances the gains were considerable as on the corn in 1916, 1920, 1921 and 1931, on the clover in 1918, 1925 and 1929, and on the oats in 1922 and 1932.

Rock phosphate with manure and limestone increased the crop yields in all cases over the manure and limestone treatment. Some of the gains were slight and others were large as, for example, on the corn in 1920, 1923, 1926 and 1927, on the oats in 1917, 1922, 1924, 1928 and 1932, and on the clover in 1918, 1919, 1925 and 1929. Superphosphate with manure and limestone also increased the crop yields in practically all cases. In some seasons superphosphate had a greater effect than rock phosphate as, for example, on the clover in 1918 and 1929, on the oats in 1932 and on the corn in 1916 and 1921. In other seasons rock phosphate had a greater influence, as on the oats in 1917, 1922, 1924 and 1928, on the clover in 1929 and on the corn in 1920, 1923, 1926, 1927, 1930 and 1931. In some instances the differences between the effects of the two phosphates were slight. The complete commercial fertilizer with manure and limestone had beneficial effects very similar to those brought about by superphosphate. In general, the differences were hardly large enough to be of any practical significance.

The Low Moor Field

The results secured in the field experiment on the Carrington silt loam on the Low Moor Field in Clinton County are given in table XI. The beneficial

TABLE X. FIELD EXPERIMENT, CARRINGTON SILT LOAM, CLINTON COUNTY, CALAMUS FIELD,* SERIES I

Plot No.	Treatment	1915 w. wheat bu. per A.	1916 corn bu. per A.	1917 oats bu. per A.	1918 clover tons per A.	1919 clover tons per A.	1920 corn bu. per A.	1921 corn bu. per A.	1922 oats bu. per A.	1923 corn bu. per A.	1924 oats bu. per A.	1925 clover tons per A.	1926 corn bu. per A.	1927 corn bu. per A.	1928 oats bu. per A.	1929 clover tons per A.	1930 corn bu. per A.	1931 corn bu. per A.	1932 oats bu. per A.
1	Check	15.9	32.9	28.8	1.45	0.58	57.5	36.0	35.9	38.8	39.2	1.10	53.5	39.7	25.0	0.76	45.5	43.2	41.4
2	Manure	26.1	46.7	54.2	3.04	0.74	65.2	43.5	45.4	47.3	50.4	1.52	57.8	44.4	38.6	0.85	43.9	49.7	44.5
3	Limestone	18.5	47.6	35.6	2.43	0.92	63.2	49.5	43.6	42.1	57.9	1.51	61.3	54.0	37.4	0.98	53.1	54.4	49.9
4	Check	19.5	44.1	35.6	2.09	0.70	54.5	39.6	37.2	38.1	50.1	1.10	49.5	40.9	25.0	0.71	49.1	52.5	42.5
5	Manure+limestone	24.0	55.5	55.9	3.38	0.74	75.7	50.9	51.8	45.2	60.2	1.86	59.6	54.7	36.3	1.35	59.4	61.2	62.4
6	Manure+limestone+rock phosphate	24.3	60.8	91.6	4.39	1.22	85.1	52.5	63.4	61.8	76.2	2.87	70.4	69.8	48.8	2.15	63.3	62.4	80.6
7	Check	21.2	42.2	37.1	3.07	0.90	58.2	44.4	36.3	38.6	54.4	1.31	52.1	33.1	21.6	0.79	55.2	52.0	70.2
8	Manure+limestone+superphosphate	27.5	61.7	77.8	5.18	2.11	70.4	57.3	57.5	52.5	72.6	2.79	60.6	43.0	34.0	1.66	59.1	58.3	94.9
9	Manure+limestone+complete commercial fertilizer	31.9	63.3	86.6	4.38	1.66	82.2	59.4	66.1	54.3	74.4	2.69	68.9	54.6	43.1	2.09	62.2	52.7	93.7
10	Check	20.6	30.1	32.3	1.47	0.52	47.9	33.3	41.4	29.0	49.4	0.89	37.2	23.0	23.8	0.49	49.3	45.4	44.3

* The Calumus Field was established in 1914 on the farm of John Olson, near Calumus, in Clinton County. It is located in the SE ¼ of Section 21, R. 2 E., Township 81 N.

TABLE XI. FIELD EXPERIMENT, CARRINGTON SILT LOAM, CLINTON COUNTY
LOW MOOR FIELD,* SERIES I

Plot No.	Treatment	1918 barley bu. per A. (1)	1919 clover and timothy tons per A. (2)	1920 timothy tons per A. (3)	1921 timothy tons per A. (4)	1922 corn bu. per A. (5)	1923 corn bu. per A.	1924 corn bu. per A. (6)	1925 barley bu. per A. (7)	1926 clover tons per A. (8)	1927 corn bu. per A.	1928 corn bu. per A.	1929 oats bu. per A.	1930 red clover tons per A.	1931 corn bu. per A. (9)	1932 corn bu. per A.
1	Check	33.0	2.07	1.98	1.08	57.4	44.3	32.0	30.8	...	22.4	40.3	53.4	0.87	38.3	53.1
2	Manure	43.0	2.31	2.13	1.24	67.7	53.9	32.5	32.6	...	40.5	54.9	65.9	1.10	32.9	71.3
3	Manure+limestone	44.4	2.46	2.77	1.39	72.3	59.6	41.6	44.6	...	46.9	60.6	63.5	1.35	24.5	80.4
4	Manure+limestone +rock phosphate	43.0	2.71	2.64	1.32	75.2	68.0	42.9	54.8	...	58.2	64.6	63.5	1.86	28.5	83.0
5	Manure+limestone +superphosphate	47.2	2.73	2.64	1.41	72.7	68.4	44.5	55.9	...	53.8	64.8	63.5	2.44	26.7	77.3
6	Manure+limestone +complete commercial fertilizer	48.6	2.67	2.81	1.41	74.3	66.0	41.1	54.4	...	58.0	64.1	76.1	2.25	30.6	78.4
7	Check	38.7	2.58	2.46	1.12	64.0	54.8	25.3	29.0	...	26.1	37.5	60.1	1.02	31.3	63.9
8	Crop residues	40.0	2.58	2.28	1.09	63.7	53.2	25.6	31.6	...	31.9	36.2	52.1	0.87	26.3	70.0
9	Crop residues+ limestone	38.7	2.80	2.47	1.38	63.1	64.9	37.6	37.4	...	30.0	53.8	64.6	1.23	23.5	70.5
10	Crop residues+ limestone+rock phosphate	42.6	2.94	2.94	1.51	57.4	68.2	48.0	43.2	...	41.7	61.5	56.8	2.40	15.4	83.2
11	Crop residues+ limestone+superphosphate	48.6	2.95	2.74	1.44	61.7	68.5	48.8	36.3	...	53.9	65.4	56.8	2.39	19.4	80.3
12	Crop residues+ limestone+complete commercial fertilizer	44.4	3.77	2.88	1.45	51.4	64.3	44.5	45.3	...	54.9	62.2	59.0	2.61	23.1	83.5
13	Check	42.6	...	2.52	1.39	47.1	57.3	30.7	30.8	...	33.0	41.5	51.0	1.39	28.6	69.8

(1) Three and one-half tons limestone applied.
(2) Plot 13 low, receives wash from rest of series.
(3) Limed September 20, 4 tons.
(4) Heavier yields on crop residue plots due to topography.
(5) Plots 10 to 13 damaged by hogs.
(6) Low yields on plots 7 and 8 could not be accounted for.
(7) Low yield on plot 11 could not be accounted for.
(8) Pastured.
(9) Hot, dry season; poor quality corn.
* The Low Moor Field was established in the fall of 1917 on the farm of Ralph Walls, near Low Moor, in Clinton County. It is located on the north side of the NE ¼ of the NE ¼ of Section 36, R. 5 E, Township 81 N.

effects of manure applied to this soil are evidenced by the increased crop yields secured in all but one season, which was the abnormally dry year, 1931. Some large increases were noted, as on the clover and timothy in 1919, on the oats in 1929, on the clover in 1930 and on the corn in 1922, 1923, 1927, 1928 and 1932. Limestone applied with manure increased crop yields further in practically all cases. Only with the oats in 1929 and the corn in 1921 was there no increase in crop yield. The clover and timothy showed the largest beneficial effect.

Rock phosphate with manure and limestone increased crop yields considerably in most seasons. Superphosphate with manure and limestone had greater effects than rock phosphate in practically all cases. The differences, however, were not large. The complete commercial fertilizer had much the same effect as superphosphate, proving somewhat preferable in some seasons, but showing smaller effects in others.

The crop residues treatment had little effect on the yields of the various crops. Limestone with the residues increased the yields notably in some seasons, as on the clover and timothy in 1929, on the timothy in 1920 and 1921, on the corn in 1923, 1924 and 1928 and on the clover in 1930.

Rock phosphate applied with limestone and crop residues increased crop yields in practically all cases. Considerable increases were noted on the timothy in 1920 and 1921, on the corn in 1924, 1927 and 1932 and on the clover in 1930. Superphosphate with residues and limestone showed larger effects than rock phosphate in several cases, but in one or two instances had a smaller beneficial effect than rock phosphate. The complete commercial fertilizer had much the same influence as superphosphate except in 1919 when it brought about a much larger effect on the clover and timothy.

The Springville Field

The results secured in the experiment on the Carrington silt loam on the Springville Field in Linn County are given in table XII. The beneficial effects

TABLE XII. FIELD EXPERIMENT, CARRINGTON SILT LOAM, LINN COUNTY SPRINGVILLE FIELD,* SERIES I

Plot No.	Treatment	1918 clover tons per A. (1)	1919 corn bu. per A. (2)	1920 corn bu. per A. (3)	1921 oats bu. per A.	1922 clover tons per A. (4)	1923 corn bu. per A. (5)	1924 corn bu. per A. (6)	1925 oats bu. per A.	1926 corn bu. per A.	1927 oats bu. per A.	1928 clover and timothy tons per A.	1929 corn bu. per A. (7)	1930 corn bu. per A. (8)	1931 oats bu. per A.	1932 corn bu. per A. (9)
1	Check	2.25	58.6	46.5	44.8	1.37	40.2	...	53.9	41.6	21.5	0.71	40.2	...	43.1	59.6
2	Manure	2.47	64.8	63.3	36.4	1.47	51.2	...	57.4	46.4	31.0	0.96	89.7	39.1	57.6	68.4
3	Manure+limestone	2.40	63.7	51.1	46.9	1.35	55.9	...	72.4	49.3	33.8	1.06	73.6	45.9	48.2	65.2
4	Manure+limestone +rock phosphate	2.70	60.8	66.1	42.8	2.02	60.2	...	71.6	50.4	45.5	1.89	93.1	51.2	55.0	68.8
5	Manure+limestone +superphosphate	2.70	67.1	60.8	46.3	2.14	59.7	...	68.6	47.4	41.9	1.92	95.2	53.0	63.0	66.9
6	Manure+limestone +complete commercial fertilizer	2.70	64.5	61.0	49.2	1.99	60.7	...	74.1	47.4	37.8	1.48	83.3	35.8	57.0	65.4
7	Check	1.65	60.0	51.9	36.9	1.35	40.0	...	43.6	34.4	35.1	0.73	65.2	38.5	48.5	60.0
8	Crop residues	2.05	62.5	55.0	42.8	1.40	46.2	...	47.4	37.8	36.8	0.91	78.7	41.8	45.4	60.1
9	Crop residues+ limestone	2.02	49.4	59.6	38.9	1.56	44.2	...	62.1	38.6	41.9	1.05	77.9	38.5	44.5	60.4
10	Crop residues+ limestone+rock phosphate	2.16	55.7	58.5	43.6	1.98	54.4	...	64.8	36.8	52.0	1.41	71.9	36.3	54.5	51.0
11	Crop residues+ limestone+superphosphate	2.47	55.4	58.5	48.4	2.10	43.5	...	62.2	37.0	48.5	1.49	66.4	46.8	58.1	56.3
12	Crop residues+ limestone+complete commercial fertilizer	2.19	33.1	57.3	37.8	2.04	44.7	...	72.4	38.6	56.6	1.22	74.5	49.2	58.4	63.9
13	Check	1.80	45.7	41.1	36.0	1.51	36.1	...	45.3	30.9	45.5	0.67	64.7	37.9	46.2	60.7

(1) Three and one-half tons limestone, fall 1917.
(2) Plots 10, 11, 12 and 13 on low ground, poor stand.
(3) Plot 2, small ditch, abnormal yield.
(4) Clover down badly on 5, 6, 11 and 12; only 85 percent could be cut.
(5) Season dry.
(6) Field was replanted and corn did not mature; no results taken.
(7) Corn harvested before mature.
(8) Plot 1 cut by mistake.
(9) Plots 10 and 11 damaged by poor drainage.

* The Springville Field was established in the fall of 1917 on the farm of F. D. Hall, near Springville, in Linn County. It is located on the east side of the NW ¼ of the SE ¼ of Section 17, R. 15 W., Township 84 N.

of manure are definitely shown in these results. Some crop increases were large as with the corn in 1922 and 1929, the oats in 1927 and the clover in 1918 and 1928. Limestone with manure increased crop yields in most seasons. In several cases benefits were large from the use of this material, as on the corn in 1920 and 1930, on the oats in 1925 and 1931 and on the clover in 1922 and 1928.

Rock phosphate with manure and limestone increased crop yields in practically all seasons. Some of the gains were striking as, for example, on the clover in 1922, on the corn in 1923 and 1929, on the oats in 1927 and on the clover and timothy in 1928. Superphosphate with manure and limestone gave larger increases than did rock phosphate in some cases, but in other instances rock phosphate proved somewhat superior. The differences were not great, however, in any case. The complete commercial fertilizer showed slightly smaller effects than superphosphate in some seasons, but in others had somewhat larger effects.

Crop residues brought about slight increases in yields in most cases. Limestone with the residues had a beneficial effect in several instances, the largest influence being secured on the oats in 1925 and on the clover in 1922 and 1928. Rock phosphate with the residues and limestone had a beneficial effect on the crops in all but four cases. The influence was large on the clover in 1922, on the corn in 1923, on the oats in 1927 and 1931 and on the clover and timothy in 1928. Superphosphate with the residues and limestone showed larger effects than rock phosphate in several seasons, but in other cases the increases were very similar to those secured with rock phosphate. In one case there was a pronounced difference in favor of rock phosphate. The complete commercial fertilizer showed a smaller effect than superphosphate in most seasons, and in those cases where larger effects were exerted, the differences were hardly large enough to be significant.

The Waverly Field

The results secured on the Carrington loam on the Waverly Field No. 2, Series I, in Bremer County are given in table XIII. The beneficial effects of manure are indicated on all but two crops, the clover in 1922 and the corn in 1930. The manure usually gave large crop increases, particularly on the corn in 1918, on the oats in 1921 and 1928 and on the sweet clover in 1932. Limestone with manure increased the yields in most seasons, showing the largest effects on the oats in 1921, 1925 and 1930, on the corn in 1927 and on the sweet clover in 1929 and 1932. The yield on plot 3 in 1919 was evidently abnormal.

Rock phosphate with manure and limestone increased the crop yields to a very pronounced extent in some seasons, but in one or two cases showed no beneficial effects. The clover in 1929, the oats in 1925 and 1928 and the corn in 1927 were greatly increased. Superphosphate showed a greater effect than rock phosphate in most seasons. The differences, however, were not large. In a few cases superphosphate had less effect than rock phosphate, and in one instance the results were almost identical. The complete commercial fertilizer had a greater influence than superphosphate in one or two cases, but in general the results were similar. Large increases were noted, however, in 1925, 1929 and 1932 from the complete commercial fertilizer.

The crop residues had little effect on the crops grown. Limestone with the residues increased the crop yields in all cases, and in some instances the gains

TABLE XIII. FIELD EXPERIMENT, CARRINGTON LOAM, BREMER COUNTY WAVERLY FIELD NO. II,* SERIES I

Plot No.	Treatment	1918 oats bu. per A. (1)	1919 clover tons per A.	1920 corn bu. per A. (2)	1921 oats bu. per A. (3)	1922 clover tons per A. (4)	1923 corn bu. per A. (5)	1924 corn bu. per A. (6)	1925 oats bu. per A. (7)	1926 sweet clover tons per A. (8)	1927 corn bu. per A.	1928 oats bu. per A.	1929 sweet clover tons per A. (9)	1930 corn bu. per A.	1931 oats bu. per A.	1932 sweet clover tons per A.
1	Check	42.8	1.50	47.8	25.7	2.22	...	11.0	....	...	40.4	35.2	0.74	54.5	31.8	0.84
2	Manure	61.0	1.75	56.5	34.3	2.20	...	24.7	63.9	...	53.3	52.2	0.87	52.2	34.9	1.06
3	Manure+limestone	64.9	1.10	57.5	50.6	2.32	...	30.4	77.7	...	65.8	45.4	1.57	61.8	38.6	2.08
4	Manure+limestone +rock phosphate	65.5	2.60	58.0	40.3	2.10	...	34.3	87.8	...	63.4	61.3	1.17	64.9	42.6	2.24
5	Manure+limestone +complete commercial fertilizer	72.1	2.35	44.0	35.7	2.78	...	42.1	103.3	...	62.9	57.9	0.97	68.9	42.6	2.39
6	Manure+limestone +superphosphate	67.2	2.85	47.0	42.0	2.90	...	38.2	89.3	...	67.3	65.8	1.22	67.2	47.4	2.65
7	Check	55.1	1.55	36.6	30.6	1.76	...	19.2	59.9	...	36.7	40.8	0.79	64.6	34.6	0.93
8	Crop residues	49.6	1.05	39.6	20.3	1.24	...	18.8	51.7	...	38.6	34.0	0.28	60.8	29.8	0.55
9	Crop residues+ limestone	66.2	1.50	40.8	30.4	1.84	...	20.3	62.1	...	55.5	44.2	1.13	67.2	36.6	1.93
10	Crop residues+ limestone+rock phosphate	70.0	1.75	41.6	40.6	2.16	...	20.5	85.3	...	59.8	54.5	1.43	66.4	37.4	2.19
11	Crop residues+ limestone+ superphosphate	88.2	2.55	43.3	38.4	2.70	...	23.1	86.9	...	61.4	58.9	1.27	63.3	42.3	2.31
12	Crop residues+ limestone+complete commercial fertilizer	88.6	2.10	45.8	46.0	2.70	...	22.4	86.5	...	51.6	58.9	1.21	66.8	43.1	2.49
13	Check	79.7	1.55	35.1	26.7	1.48	...	16.3	53.4	...	33.4	38.6	0.14	63.0	32.1	0.58

(1) Six tons limestone in fall 1917.
(2) Soybeans planted in corn, both crops poor. Wet spring injured plots in center series; plots 5 and 6 and crop residue plots weedy.
(3) Plot 3 too high; many morning glory vines on plot.
(4) Stand uneven on 2 and 4.
(5) Corn replanted; did not mature.
(6) Crop damaged by frost; phosphate plots showed more maturity.
(7) Barley seeded by mistake on plot 1. Unable to account for high yield on plot 5.
(8) Field pastured; no results taken.
(9) Plots damaged by sheep.
* The Waverly Field No. II, Series I, was established in the fall of 1917 on the George Christophel farm, northwest of Waverly, in Bremer County. The series is located in the southwest part of the SW ¼ of the NW ¼ of Section 28, T. 92 N, R. 14 W. in Lafayette Township.

were large, particularly on the clover in 1919 and 1922, on the corn in 1927 and 1930 and on the sweet clover in 1929 and 1932. Large effects were also shown on the oats in 1921, 1925, 1928 and 1931.

Rock phosphate with the crop residues and limestone increased the crop yields considerably in practically all cases. The largest influence was noted on the clover crop, on the sweet clover and on the oats in 1925 and 1928. Superphosphate with the residues and limestone had a larger effect than rock phosphate in practically every season. The gains were sometimes pronounced, as on the clover in 1919 and 1922. In 1930 superphosphate showed less effect than rock phosphate. The complete commercial fertilizer with the crop residues and limestone had about the same effect as did superphosphate, showing a slightly greater influence in some cases and smaller in others.

The results secured on the Waverly Field, Series II, are given in table XIV. The manure resulted in large increases in crop yields in practically every season.

TABLE XIV. FIELD EXPERIMENT, CARRINGTON LOAM, BREMER COUNTY
WAVERLY FIELD NO. 2,* SERIES II

Plot No.	Treatment	1918 corn bu. per A. (1)	1919 oats bu per A.	1920 clover tons per A. (2)	1921 clover and timothy tons per A.	1922 corn bu. per A. (3)	1923 corn bu. per A. (4)	1924 oats bu. per A. (5)	1925 sweet clover tons per A.	1926 alfalfa tons per A. (6)	1927 alfalfa tons per A. (7)	1928 alfalfa tons per A. (7)	1929 alfalfa tons per A. (7)	1930 alfalfa tons per A. (7)	1931 corn bu. per A. (8)	1932 corn bu. per A.
1	Check	38.5	39.8	0.47	1.03	39.4	25.0	42.8	0.39	...	0.51	0.35	0.93	0.46	37.2	48.1
2	Manure	54.0	49.3	0.67	1.30	55.7	40.2	49.7	0.45	0.76	1.46	1.87	1.85	1.77	44.5	68.5
3	Manure+limestone	56.8	61.9	1.36	1.87	62.3	57.0	66.4	2.66	1.28	2.52	3.00	2.83	2.70	42.0	67.5
4	Manure+limestone +rock phosphate	57.2	46.4	1.66	1.98	63.1	62.0	64.9	2.72	1.61	3.19	3.18	3.23	3.52	35.3	77.1
5	Manure+limestone +superphosphate	60.5	57.8	2.05	2.19	64.0	60.7	75.8	3.03	1.65	3.18	2.88	3.58	3.90	35.4	75.2
6	Manure+limestone +complete commercial fertilizer	61.3	61.9	1.99	2.47	62.9	63.0	65.3	3.03	1.35	3.12	3.30	3.17	3.72	37.9	86.5
7	Check	48.7	35.4	0.84	1.17	45.7	34.2	42.5	0.62	0.67	0.96	1.29	1.26	1.28	35.9	58.6
8	Crop residues	46.4	39.4	0.67	1.09	41.4	34.0	48.3	0.62	0.69	0.79	1.21	0.85	0.97	36.1	51.2
9	Crop residues+ limestone	50.0	48.3	0.87	1.26	50.6	45.2	55.5	2.93	1.10	1.72	2.40	2.60	2.44	40.9	61.5
10	Crop residues+ limestone+rock phosphate	56.7	40.8	1.14	1.44	52.0	46.5	74.7	3.02	1.11	2.04	2.35	2.48	2.71	39.9	59.9
11	Crop residues+ limestone+superphosphate	48.7	47.3	1.11	1.63	51.4	47.5	70.9	3.02	1.36	2.21	2.55	3.18	1.88	36.4	59.1
12	Crop residues+ limestone+complete commercial fertilizer	42.7	53.5	1.32	2.10	60.8	50.7	51.2	2.96	1.31	2.55	3.14	2.21	1.43	40.9	67.4
13	Check	33.4	32.9	0.33	0.87	34.8	43.2	37.8	0.45	0.69	0.36	0.87	0.84	0.47	37.8	50.0

(1) Six tons limestone, fall 1917. Heavy rains washed 11, 12 and 13 badly.
(2) Plots 1 and 2 poorer in fertility than other plots.
(3) Dry season.
(4) Plot 13 high, probably due to manure application made through error.
(5) Low yield on plot 12 due to part of crop lost in threshing.
(6) Grasshoppers destroyed the crop on plot 1 and damaged west side of all plots. One cutting.
(7) Two cuttings. First cutting mostly timothy on plots 1 and 13. Timothy seeded in 1926 to thicken stand.
(8) Hot, dry season.
* The Waverly Field No. II, Series II, was established in the fall of 1917 on the farm of George Christophel, northwest of Waverly, in Bremer County. It is located in the NW ¼ of the NW ¼ of Section 28, T. 92 N, R. 14 W. in Lafayette Township.

The clover in 1920 and 1921, the corn in 1922, 1923 and 1932 and the alfalfa in 1927, 1928, 1929 and 1930 showed the largest influence from the use of manure. The application of limestone with manure brought about distinct gains in the crop yields in practically every season. The gains were often very large, as on the clover in 1920 and 1921, on the sweet clover in 1925, on the corn in 1923, on the oats in 1924 and on the alfalfa in 1926, 1927, 1928, 1929 and 1930.

Rock phosphate with manure and limestone increased the crop yields in most seasons. The differences, however, were small. Superphosphate with manure and limestone increased the yields considerably in most seasons, the largest effect being noted on the clover and alfalfa, although there was also a large effect on the oats in 1924. The complete commercial fertilizer with manure and limestone had a somewhat greater effect than superphosphate in some cases, but in other instances it did not bring about as large increases.

The crop residues had little effect on the crop yields. Limestone with the residues increased the yields in a very pronounced way as, for example, on the sweet clover in 1925, on the alfalfa in 1926, 1927, 1928, 1929 and 1930, and on the corn in 1932.

Rock phosphate with the crop residues and limestone increased the yields in most cases, the influence being considerable on the clover crop and on the oats in 1924. Superphosphate with the residues and limestone showed a larger effect than rock phosphate in one or two cases, but the differences were small and the returns were generally about the same. The complete commercial fertilizer showed a larger effect than superphosphate in some cases, particularly on the clover and timothy in 1921, on the alfalfa in 1927 and 1928 and on the corn in 1932, but in other instances there were smaller effects from the complete fertilizer.

The Eldora Field

The results secured on the Carrington loam, Series 200, on the Eldora Field in Hardin County are given in table XV. Manure greatly increased the yields of crops in practically all seasons. Some very large gains were noted, as on the clover in 1918, on the oats in 1921 and 1925 and on the barley in 1932. Corn yields were increased appreciably in practically all instances. Only in one or two cases were no increases noted. The application of limestone with manure increased the crop yields in most seasons, showing the largest beneficial effects on the clover in 1918, on the oats in 1926 and on the corn in 1928. In several seasons no gains were obtained with the limestone.

Rock phosphate with manure and limestone brought about pronounced increases in the yields of crops in practically all seasons. Large effects were evidenced on the clover in 1918, 1922 and 1930. The oats in 1917, 1921, 1925, 1926 and 1929 were increased, the largest effect being shown on this crop in 1925. Corn was benefited to a considerable extent in all seasons, the largest effect appearing on this crop in 1927. Superphosphate with manure and limestone brought about a larger beneficial effect on the yields in some seasons than did rock phosphate. There was a much greater effect from superphosphate on the oats in 1917, 1926, 1929 and on the clover in 1922. Greater effects were also shown on the corn in 1919, 1923 and 1927, but the differences in the effects of the two phosphates were small. The complete commercial fertilizer with manure and limestone had about the same effect as superphosphate in most cases, showing up to a somewhat greater advantage in some seasons, but having a smaller effect in others.

The crop residues had little effect on the crops grown in most seasons. Limestone with the residues brought about slight increases. Rock phosphate with the residues and limestone increased the yields in practically all cases, especially with the corn in 1927. Superphosphate with the residues and limestone showed larger effects than rock phosphate in most seasons. The greatest benefits were evidenced on the clover in 1918 and 1922, on the oats in 1921, and on the corn in 1919, 1920, 1924 and 1927. The differences in the case of the corn yields, however, were not very pronounced. In one or two cases rock phosphate showed up to a better advantage. The complete commercial fertilizer with

TABLE XV. FIELD EXPERIMENT, CARRINGTON LOAM, HARDIN COUNTY, ELDORA FIELD,* SERIES 200

Plot No.	Treatment	1917 oats bu. per A. (1)	1918 clover tons per A. (2)	1919 corn bu. per A.	1920 corn bu. per A. (3)	1921 oats bu. per A.	1922 clover tons per A. (4)	1923 corn bu. per A. (5)	1924 corn bu. per A. (6)	1925 oats bu. per A. (7)	1926 oats bu. per A.	1927 corn bu. per A.	1928 corn bu. per A.	1929 oats bu. per A.	1930 clover tons per A.	1931 corn bu. per A. (8)	1932 barley bu. per A.
1	Check	60.1	0.54	46.4	60.9	26.6	1.17	41.5	31.6	38.1	20.6	39.5	53.7	26.1	0.80	23.8	16.5
2	Manure	66.4	0.90	50.0	62.5	38.0	1.38	37.6	30.3	48.6	20.5	45.0	56.3	29.5	0.94	9.0	29.4
3	Manure+limestone	65.7	1.00	51.8	65.6	41.8	1.31	40.0	23.3	48.3	27.7	38.0	62.6	34.0	0.95	6.4	31.0
4	Manure+limestone+rock phosphate	72.6	1.85	53.6	71.8	50.3	2.06	42.1	30.0	69.0	30.3	49.8	65.7	41.9	1.55	14.6	26.6
5	Manure+limestone+superphosphate	85.5	1.51	57.2	68.7	48.7	2.57	46.6	30.0	72.6	37.3	51.2	60.9	48.8	1.56	16.9	33.1
6	Manure+limestone+complete commercial fertilizer	80.0	1.48	51.7	59.3	54.6	2.61	53.2	28.1	79.9	41.9	48.6	58.8	45.4	1.54	18.0	54.0
7	Check	62.0	0.45	48.8	42.1	36.9	1.88	38.2	18.3	49.7	28.4	26.6	36.4	29.5	0.46	21.6	16.5
8	Crop residues	61.8	0.41	50.7	35.9	32.3	1.80	36.9	18.3	49.0	27.5	26.6	31.9	35.1	0.33	24.1	12.9
9	Crop residues+limestone	63.0	0.47	50.8	35.9	29.2	1.41	43.2	19.0	51.5	26.4	23.0	38.8	36.3	0.45	21.1	13.7
10	Crop residues+limestone+rock phosphate	69.2	0.49	60.0	45.3	22.0	2.13	40.5	19.7	59.4	27.2	33.9	40.5	35.1	0.98	11.2	19.4
11	Crop residues+limestone+superphosphate	67.6	0.74	62.5	48.4	32.2	2.32	40.0	21.7	56.6	27.7	36.4	35.9	34.0	1.10	13.9	23.4
12	Crop residues+limestone+complete commercial fertilizer	66.4	0.51	55.3	59.3	37.2	2.60	46.6	21.7	62.4	35.0	39.9	39.5	43.1	1.65	21.2	26.2
13	Check	60.0	0.38	52.1	48.4	28.6	1.68	31.5	10.0	45.0	28.4	31.4	35.4	28.3	0.47	39.7	16.5

(1) Three tons of limestone applied in 1916.
(2) Crop poor; dry season.
(3) Plots 5, 6, 7, 8 and 9 poor, due to wet spring. Limestone applied, 3 tons per acre.
(4) Poor stand on plots 1, 2 and 3.
(5) Dry season; poor stand.
(6) Poor drainage on plot 13.
(7) Plots 7, 8 and 13 are poorly drained.
(8) Hot, dry season; poor quality corn.

* The Eldora Field, Series 200, was established in the fall of 1914 on the farm of the State Training School for Boys, at Eldora, in Hardin County. No crop was harvested in 1915 and potatoes were grown in 1916. The series is located in the same field as Series 100 in the SW ¼ of the NW ¼ of Section 12, T. 87 N., R. 20 W. in Pleasant Township.

the residues and limestone had a greater effect than superphosphate in a number of cases, showing up particularly well on the corn in 1920 and 1923, on the clover in 1922 and 1930 and on the oats in 1925, 1926 and 1929. The differences in other seasons were small and mostly slightly in favor of the complete fertilizer.

The Jesup Field

The results secured in the experiment on Carrington loam on the Jesup Field in Black Hawk County are given in table XVI. The beneficial effects of manure on this soil are evidenced by the increased crop yields secured in practically all seasons. Large gains resulted from the application of manure on the clover in 1919, on the clover and timothy in 1920 and 1931 and on the corn in 1921, 1922, 1926, 1927 and 1929. Limestone with manure increased the yields of crops in many cases. The oats in 1918 and 1930, the clover and timothy in 1920 and 1931,

TABLE XVI. FIELD EXPERIMENT, CARRINGTON LOAM, BLACK HAWK COUNTY JESUP FIELD,* SERIES II

Plot No.	Treatment	1918 oats bu. per A. (1)	1919 clover tons per A.	1920 clover and timothy tons per A. (2)	1921 corn bu. per A.	1922 corn bu. per A.	1923 oats bu. per A. (3)	1924 clover tons per A. (4)	1925 clover tons per A. (5)	1926 corn bu. per A. (6)	1927 corn bu. per A. (7)	1928 oats bu. per A. (8)	1929 corn bu. per A. (9)	1930 oats bu. per A.	1931 clover and timothy tons per A. (10)	1932 clover and timothy tons per A. (11)
1	Check	71.9	1.17	0.50	58.7	51.4	31.7	0.92	...	47.2	28.2	45.4	28.4	44.3	0.52	...
2	Manure	71.6	2.08	0.85	72.8	65.6	29.4	1.06	...	60.5	34.2	45.4	38.5	44.8	0.70	...
3	Manure+limestone	83.1	1.92	1.20	77.6	71.1	37.3	1.26	...	60.0	45.9	53.3	46.7	59.0	1.14	...
4	Manure+limestone +rock phosphate	81.8	1.86	1.15	78.1	73.4	41.8	1.29	...	72.5	44.9	63.5	53.8	49.4	1.24	...
5	Manure+limestone +superphosphate	76.1	2.22	1.12	75.5	73.4	45.3	1.65	...	73.3	42.9	66.9	45.6	52.3	1.11	...
6	Manure+limestone +complete commercial fertilizer	77.2	2.80	1.25	78.7	77.6	44.2	1.60	...	65.3	40.3	62.4	50.8	54.8	1.27	...
7	Check	60.8	1.38	0.47	54.0	53.7	34.0	0.58	...	34.1	17.2	49.9	24.6	48.8	0.26	...
8	Crop residues	64.0	1.36	0.52	56.5	56.0	38.3	0.88	...	...	...	...	...	...	...	...
9	Crop residues+ limestone	64.9	1.15	0.42	46.4	52.0	36.3	1.15	...	...	...	...	...	...	...	...
10	Crop residues+ limestone+rock phosphate	63.6	1.53	0.42	60.8	60.8	38.7	1.23	...	...	...	...	...	...	...	...
11	Crop residues+ limestone+superphosphate	62.5	1.53	0.60	67.6	62.6	38.3	1.62	...	...	...	...	...	...	...	...
12	Crop residues+ limestone+complete commercial fertilizer	75.7	1.77	0.70	72.8	70.2	38.3	1.67	...	...	...	...	...	...	...	...
13	Check	67.8	1.20	0.65	60.2	55.4	34.0	1.18	...	...	...	...	...	...	...	...

(1) Three and one-half tons limestone applied.
(2) Plots 9 and 10 in swale and poorly drained.
(3) Oats thin; dry season.
(4) Plot 7 poor due to poor drainage; plot 13 high, due to old yeard location.
(5) Plots were pastured.
(6) Crop residue plots were left in pasture and not plowed.
(7) Plots 8, 9, 10, 11, 12 and 13 were still in pasture.
(8) Plots 8, 9, 10, 11, 12 and 13 in pasture.
(9) Crop residue plots discontinued.
(10) Timothy only on plots 1, 2 and 7.
(11) Plots pastured, no results.

* The Jesup Field, Series II, was established in the fall of 1917 on the farm of William Thompson, west of Jesup, in Black Hawk County. It is located in the SW corner of the SE 1/4 of the NW 1/4 of Section 26, T. 89 N, R. 11 W. in Barclay Township.

the clover in 1924, the corn in 1927 and the oats in 1923 and 1928, showed pronounced effects from the addition of limestone.

Rock phosphate with manure and limestone increased the crop yields in several seasons, although no large increases were secured. Only with the corn in 1926 and 1929 and the oats in 1928 were large increases secured from this fertilizer, and in one or two cases no increases were obtained. Superphosphate with manure and limestone had a larger effect than rock phosphate in one or two instances, as for example, on the clover in 1919 and 1924 and on the oats in 1928. In most seasons small differences between the effects of the two phosphates were noted. The complete commercial fertilizer with manure and limestone increased the crop yields slightly more than did superphosphate in most seasons. In general, however, the differences were slight, and in one or two cases the complete commercial fertilizer showed less effect than superphosphate.

The crop residues had little effect on the crops grown in most seasons. In one or two cases increases were secured as on the clover in 1924. Limestone with the residues increased the crop yields only in one or two seasons.

Rock phosphate with the crop residues and limestone brought about pronounced increases in the yields of crops in several cases, but in two instances no effects were noted. Superphosphate with the residues and limestone had a greater effect than rock phosphate in most seasons. Some of the differences in favor of superphosphate were very pronounced, as on the clover and timothy in 1920 and the clover in 1924. The complete commercial fertilizer with the crop residues and limestone had a larger effect than superphosphate on most of the crops grown. Some of the gains were considerable as on the oats in 1918, on the clover in 1919 and on the corn in 1920.

The Independence Field

The results secured on the Carrington loam on the Independence Field in Buchanan County are given in table XVII. The application of manure increased crop yields in all but one season, showing very large effects in practically all cases. The largest increases were obtained on the corn in 1921, 1924, 1925, 1929 and 1932, on the oats in 1926 and 1930, on the clover and timothy in 1923 and on the clover in 1927 and 1931. Limestone with manure showed beneficial effects on the crops grown in all but one season, the largest benefits from the application appearing on the timothy and clover in 1923 and the clover in 1931.

Rock phosphate with manure and limestone showed beneficial effects on the crops in most seasons. The largest increases were secured on the timothy and clover in 1923, and on the oats in 1930. It had no influence on the corn in 1924, 1925, 1932, nor on the oats in 1926. It showed small beneficial effects in most other seasons. Superphosphate with manure and limestone showed larger effects than rock phosphate in several seasons. It had a much greater effect on the corn in 1924 and on the oats in 1926 and showed slightly larger benefits in other seasons. It had less effect than rock phosphate, however, on the timothy and clover in 1923 and on the oats in 1930. The effects on the corn in 1928, 1929 and 1932 were very similar for the two phosphates. The complete commercial fertilizer with manure and limestone showed less effect than superphosphate in most seasons. It had somewhat larger effects on the corn in 1928, 1929 and 1932, and on the clover in 1931, but in all other cases it was less effective than superphosphate.

The crop residues had little effect on the crops grown in most seasons. Clover in 1927 and 1931 and the corn in 1929 showed some beneficial effects. Limestone with the residues increased the crop yields in all but one season. The largest beneficial effect appeared on the timothy and clover in 1923 and on the oats in 1930. There was also a considerable effect on the oats in 1926. The corn in 1928 was the only crop not benefited by the limestone.

Rock phosphate with the crop residues and limestone increased the crop yields in most seasons. It had no effect on the oats in 1922, the clover in 1927 nor on the oats in 1930. Beneficial effects were found in all other cases. The largest beneficial influence appeared on the clover and timothy in 1923 and on the clover in 1931. Superphosphate with the residues and limestone showed a much greater effect than rock phosphate on the oats in 1922 and a greater effect also in several other seasons. It had less influence than rock phosphate, however, on the corn in 1928, 1929 and 1932, the timothy and clover in 1923 and the clover in 1931. The complete commercial fertilizer with the residues and limestone showed slightly larger effects than superphosphate in a number of cases. The timothy and clover in 1923, the clover in 1927 and the oats in 1930 were benefited materially by the complete fertilizer. Large effects also appeared in the case of the corn in 1924, 1925 and 1929 and on the oats in 1926. In most other seasons superphosphate had the greater influence.

TABLE XVII. FIELD EXPERIMENT, CARRINGTON LOAM, BUCHANAN COUNTY INDEPENDENCE FIELD,* SERIES II

Plot No.	Treatment	1921 corn bu. per A. (1)	1922 oats bu. per A.	1923 clover and timothy tons per A.	1924 corn bu. per A. (1)	1925 corn bu. per A. (1)	1926 oats bu. per A. (1)	1927 clover tons per A.	1928 corn bu. per A. (1)	1929 corn bu. per A.	1930 oats bu. per A. (1)	1931 red clover tons per A.	1932 corn bu. per A.
1	Check	49.4	61.4	1.55	37.8	39.0	20.1	1.48	49.9	48.5	31.2	1.39	39.6
2	Manure	64.0	57.2	1.94	57.6	59.0	62.6	2.12	57.4	65.2	61.5	1.59	50.3
3	Manure+limestone	69.0	64.4	2.33	59.3	64.6	59.9	2.17	62.8	70.8	62.1	1.93	54.9
4	Manure+limestone+rock phosphate	69.0	69.9	2.72	56.2	69.4	55.0	2.23	63.9	62.9	75.0	1.88	54.1
5	Manure+limestone+superphosphate	70.3	71.4	2.34	61.3	70.8	63.9	2.31	63.7	62.8	72.6	1.93	53.6
6	Manure+limestone+complete commercial fertilizer	67.1	65.9	2.14	62.0	65.7	55.2	2.26	69.2	67.5	74.1	2.03	56.4
7	Check	59.0	64.6	1.16	54.5	53.8	44.6	1.59	57.4	41.9	66.1	1.42	53.5
8	Crop residues	65.0	64.3	1.16	58.1	54.4	43.6	1.88	58.9	47.6	67.5	1.62	55.3
9	Crop residues+limestone	73.3	66.8	1.75	62.9	61.8	54.5	1.91	53.2	50.5	71.1	1.66	52.4
10	Crop residues+limestone+rock phosphate	76.4	50.6	1.95	64.3	63.0	55.5	1.50	54.0	53.2	70.8	2.07	55.7
11	Crop residues+limestone+superphosphate	72.7	64.4	1.75	64.8	66.4	56.8	1.56	47.6	47.9	70.8	1.72	53.8
12	Crop residues+limestone+complete commercial fertilizer	68.1	61.2	1.99	70.2	69.8	63.0	1.80	46.8	57.2	77.7	1.85	54.8
13	Check	53.3	49.9	1.36	55.3	56.0	63.3	1.80	53.8	57.2	66.2	1.74	53.9

(1) Plot 1 is affected by a grove of trees near it.

* The Independence Field, Series II, was established in the fall of 1920 on the State Hospital farm, at Independence, in Buchanan County. It is located in the NW corner of the SW ¼ of the SE ¼ of Section 6, T. 88 N, R. 9 W. in Sumner Township.

THE NEEDS OF BUTLER COUNTY SOILS AS INDICATED BY LABORATORY, GREENHOUSE AND FIELD TESTS

The results which have been secured in the laboratory, greenhouse and field experiments on the soils from Butler County indicate the natural fertility and something of the fertilizer needs of these soils. Some general recommendations regarding the management of the soils in the county may, therefore, be given here. Specific suggestions for individual types will be given wherever possible in the discussion of the various soil types later in the report.

LIMING

The analyses of the soils of the county given earlier in this report show that all types except the Fargo silty clay loam on the terraces are acid in reaction, the acidity extending down through the lower soil layers to a depth of 40 inches. The extent of the acidity is indicated by the figures given for the lime requirements of the soils. These figures should be considered only roughly indicative of the lime needs of the soils, however. Soils vary greatly in acidity, and even soils of the same type in different fields will show considerable differences in lime requirements. The soil in every field should be tested and its need for lime determined before any application is made. In this way only is it possible to make the proper application. Soils will be tested free of charge by the Soils Subsection of the Iowa Agricultural Experiment Station, and if farmers will send in samples of their soils, they may readily ascertain the lime needs of their soils and secure other suggestions as to desirable treatments for their land.

In general, the most satisfactory crop yields are secured on soils which have been limed or are not acid in reaction. Grain crops are not so sensitive to acidity and may grow well on acid soils, but they will generally show considerable benefits from the application of limestone. If not benefited directly, corn and small grains will be increased by the use of lime in the rotation, because of the greater legume growth and hence increased leguminous residues left in the soil. The common legumes used in crop rotations are very sensitive to acidity and in the case of alfalfa, and sweet clover, liming acid soils is absolutely necessary if a crop is to be secured. These legumes may fail entirely on acid soils. It is also necessary to lime to obtain the best yields of other legumes.

Large crop increases may be secured on the acid soils in Butler County by the application of lime as needed. The experiments discussed earlier have indicated the large beneficial effects obtained on the Carrington silt loam and the Carrington loam, the two most extensively developed soils in the county. All the soils in the county except the Fargo silty clay loam would be benefited by the use of lime, some perhaps to a greater extent than those tested in the experiments. The practical experiences of many farmers confirm the results of the tests reported here and indicate the large benefits which may be secured from liming acid soils.

It is recommended that the soils in the county except the Fargo silty clay loam be tested once in the rotation, just preceding the growing of the legume crop, and if lime is needed, an application be made. In this way growth of the legume will be insured. One treatment with lime may not suffice for more than one rotation. If it does, then the test of the soil will show no acidity, and hence no lime need be applied. But a test is desirable to insure the best conditions for legume growth.

MANURING

While some of the soils in Butler County are apparently well supplied with organic matter, as is evidenced by their dark color, many types in the county are rather poorly supplied with organic matter and hence low in productivity. The application of fertilizers supplying organic matter is very necessary now on these latter, lighter-colored soils, many of which are sandy in texture. The regular application of similar fertilizing materials is needed also on the better, richer soils, if the supply of organic matter is to be kept up and these types are to remain fertile.

The Dickinson and Lindley soils on the drift uplands the Fayette very fine sandy loam on the loessial upland, the O'Neill and Millsdale soils on the terraces and the Cass sandy loam and Wabash loam on the bottoms are especially in need of organic matter, and fertilizing materials supplying it should be applied to increase production of profitable crops. But additions to many of the other types in the county such as the Carrington, the Dodgeville, the Floyd and Tama soils will also prove of value, and on all these types the regular application of materials supplying organic matter will be needed to provide against any deficiency in the future.

The greenhouse and field experiments discussed earlier in this report have shown the value of farm manure when applied to the Carrington loam and silt loam. Other types would undoubtedly show as great or even greater beneficial effects from the application of farm manure. It is certainly one of the most valuable fertilizing materials which can be employed on the soils of this county. It is also the cheapest and best source of organic matter. Its use will be of particularly large effect on the lighter colored, sandy soils, but benefits are also large on the darker-colored richer soils.

On most farms, the production of farm manure is entirely inadequate to permit regular addition to all the land on the farm, and hence some other fertilizing material supplying organic matter must be utilized. The turning under of legumes as green manures, therefore, is a practice of large value. By its use, large amounts of organic matter and nitrogen are added to the soil.

The lighter colored, sandy types in Butler County will certainly be benefited by utilizing some legumes as a green manure and the practice is to be recommended on such soils. On all the soils the practice should be put into operation, however, if the supply of farm manure is insufficient to permit regular applications. Green manuring is not a practice to be followed carelessly or blindly, however, as the results may not be entirely beneficial if decomposition of the green material is not as rapid as it should be.

The supply of organic matter in all soils may also be kept up in part, by the proper use of crop residues. Such materials should never be burned or otherwise destroyed as they are needed in all soils. They are not sufficient to keep up the organic matter in soils, but they aid materially. When they are properly used along with farm manure and leguminous green manures, the supply of organic matter in soils may be built up and kept up.

THE USE OF COMMERCIAL FERTILIZERS

The total supply of the essential plant food element, phosphorus, is not great in any of the soils in Butler County, and in many cases the content is so low that there is certainly a deficiency in available phosphorus now. The application of a phosphorus fertilizer appears to be desirable now on much of the land in the county and will certainly be necessary in the near future on all cultivated areas.

Large crop increases have been secured from the use of rock phosphate or superphosphate on some of the soils in the county according to the field and greenhouse tests. The beneficial effects on the Carrington silt loam and the Carrington loam have been particularly noted in the experiments referred to. Just as great or even greater benefits would undoubtedly be secured on other types in the county.

In some of the tests superphosphate seemed to be more effective, but in others rock phosphate proved quite as desirable for use. While superphosphate is more expensive than rock phosphate, it is applied in smaller amounts so that the application actually costs less. The usual amount used is 120 pounds per acre annually, or 3 years out of 4 in the 4-year rotation, or a total of 360 pounds per rotation. Rock phosphate is usually applied once in the rotation at the rate of 1,000 pounds per acre, or 500 pounds at the lowest. The phosphorus in superphosphate is readily available for plant use, while it takes some time for the element in the rock phosphate to be changed into a form in which it can be utilized. Thus, rock phosphate usually gives the greatest effect the second year after application, while superphosphate shows its effect the first year. The relative value of these two phosphates for the soils of Butler County has not yet been definitely determined. It is recommended, therefore, that farmers test both materials on small areas under their particular conditions and thus determine which should be used extensively on their land.

The nitrogen content of many of the soils in Butler County is rather low and a need of some fertilizing material supplying nitrogen is indicated. But on all the soils, even those which are apparently well supplied now, the nitrogen content must be kept up by regular additions, if it is not to become deficient. Nitrogen is lost from soils regularly and rapidly in crops grown and removed and in drainage waters, and unless fertilizers supplying the element are used, soils soon show a definite loss of fertility.

The use of farm manure aids much in keeping up the supply of nitrogen in the soil, returning as it does large amounts of this element contained in the crops grown and used as feed on the farm. But the losses from manure are great, and the amount of manure produced is usually far less than would be needed to supply all the land on the farm, and hence some other nitrogen source must be sought. Crop residues also aid in keeping up the nitrogen in soils, but they, too, are obviously quite inadequate. The turning under of well-inoculated legumes as green manures is the best means of increasing the nitrogen content of the soil. Such crops, when well-inoculated, are able to draw upon the nitrogen content of the atmosphere, and when plowed down they add considerable amounts of nitrogen to the soil, along with the organic matter which is also of much fertility value. The practice of green manuring with legumes would certainly be worth while on many of the soils in Butler County now, especially on the lighter-colored sandy types. But even on the better soils the practice will also prove of value, and even with a utilization of all crop residues and the use of the farm manures produced on the average livestock farm, the use of legumes as green manures is very desirable.

The nitrogen content of soils may be built up and kept up most cheaply by the use of legumes as green manures, and hence the use of commercial nitrogenous fertilizers cannot be generally recommended. Such commercial materials may occasionally be used as top dressings for certain crops, such as truck crops, and prove of value. But they should always be tested on small areas and their value determined before applications are made extensively.

The use of commercial potassium fertilizers cannot be recommended generally for the county. Previous analyses have indicated that the soils are well supplied with potassium, and there should be no need of adding this element for many years to come. The tests thus far carried out have not shown any large value from the use of potassium fertilizers for general farm crops, but they may be found distinctly beneficial in some cases. Small amounts as top dressings for certain special crops may also prove of value. Tests of the value of potassium carriers should always be conducted on small areas before extensive applications are made.

Complete commercial fertilizers may be used profitably on some of the soils in Butler County. The tests reported earlier have shown the crop increases which may be secured from the use of certain complete brands on two of the more important types in the county. But it appears that the phosphates may have quite as large effects as the complete fertilizers at less expense. The complete fertilizers must give much larger crop increases than phosphates, if they are to prove as economically desirable. Tests should be carried out, however, comparing the complete fertilizer with superphosphate, before any large application of a complete brand is made, since the superphosphate may prove quite as effective and hence more profitable.

DRAINAGE

The natural drainage system of Butler County is well developed, and most of the land in the county is well drained. In some areas, however, the drainage is inadequate. On the flat or depressed areas of the Clyde silt loam and Clyde silty clay loam and on areas in other upland types, artificial drainage is needed if crop yields are to be satisfactory. On the Bremer and Fargo types on the terraces and on the heavier bottomland soils, the drainage is poor. In the case of the latter soils, it is necessary, of course, to protect the land from overflow also if it is to be satisfactorily cropped.

In general, it may be said that wherever drainage is not entirely satisfactory, the installation of tile will be of great value. Crops will not grow satisfactorily on land which is too wet. On some of the soils in the county and particularly the flat to depressed areas, tiling is the first treatment needed to make the land productive. Often it may make the land produce a good crop where prior to tiling, crops have failed regularly.

THE ROTATION OF CROPS

The continuous growing of one crop reduces the fertility of the soil very quickly and brings about a rapid decline in crop yields. The actual economic returns from a good rotation over a period of years have been found to be greater than for continuous cropping.

No specific rotations can be recommended for use in Butler County as no tests have been carried out. But some general recommendations may be offered here regarding desirable rotations. Any of the rotations mentioned may be chosen for use or may serve as a basis upon which a rotation may be worked out for any particular conditions. In fact, almost any rotation will be worth while for use, if it contains the money crops and a legume at regular intervals.

1. Six-Year Rotation

First year—Corn
Second year—Corn
Third year—Wheat or oats (with clover, or clover and grass)
Fourth year—Clover, or clover and grass
Fifth year—Wheat (with clover, or grass and clover)
Sixth year—Clover, or clover and grass

This rotation may be reduced to a 5-year rotation by cutting out either the second or sixth year, and to a 4-year rotation by omitting the fifth and sixth years.

2. Four or Five-Year Rotation

First year—Corn
Second year—Corn
Third year—Wheat or oats (with clover, or clover and timothy)
Fourth Year—Clover (If timothy was seeded with the clover the preceding year, the rotation may be extended to 5 years. The last crop will consist principally of timothy.)

3. Four-Year Rotation with Alfalfa

First year—Corn
Second year—Oats
Third year—Clover
Fourth year—Wheat
Fifth year—Alfalfa (This crop may remain on the land 5 years. The field should then be used for the 4-year rotation outlined above and the alfalfa shifted to one of the fields which was previously in the 4-year rotation.)

4. Four-Year Rotations

First year—Wheat (with clover)
Second year—Corn
Third year—Oats (with clover)
Fourth year—Clover

First year—Corn
Second year—Wheat or oats (with clover)
Third year—Clover
Fourth year—Wheat (with clover)

First year—Wheat (with clover)
Second year—Clover
Third year—Corn
Fourth year—Oats (with clover)

5. Three-Year Rotations

First year—Corn
Second year—Oats or wheat (with clover seeded in the grain)
Third year—Clover (In grain farming only the grain and clover seed should be sold, most of the crop residues, such as corn stover, should be plowed under. The clover may be clipped and left on the land to be returned to the soil and only the seed taken from the second crop.)

First year—Corn
Second year—Oats or wheat (with sweet clover)
Third year—Sweet clover (The clover may be mixed clover and used largely as pasture and green manure.) (This may be changed to a 2-year rotation by plowing the sweet clover under the following spring for corn.)

First year—Wheat (with clover)
Second year—Corn
Third year—Cowpeas or soybeans

THE PREVENTION OF EROSION

Erosion is the carrying away of soil through the movement of water over the surface of the land. There are two types of erosion, sheet washing and gullying. Sheet erosion is the washing away of the surface soil. Gullying is more striking in appearance, since gulches or ravines may be formed.

Erosion occurs to some extent in Butler County. On the drift uplands the Lindley soils are subject to much washing, and some areas of the Carrington and Dickinson types are also affected. Some washing may also occur on the Tama soils on the loessial uplands. Wherever erosion occurs some means to prevent or control it should be adopted.

Various methods are followed for the control or prevention of erosion in Iowa. These methods differ somewhat, depending upon the type of erosion. Erosion due to dead furrows may be controlled by ''plowing in,'' by ''staking in'' or by the use of earth dams.

Small gullies may be filled by the ''staking in'' operation, by the use of straw dams, earth dams, Christopher or Dickey or Adams dams, stone dams, rubbish dams, woven-wire dams or concrete dams. They may be prevented from occurring by thorough drainage or by the use of sod strips. Large gullies may be similarly filled or prevented from occurring. Erosion in bottomlands may be prevented by straightening the streams, by tiling and by planting trees up the drainage channels. Hillside erosion may be controlled by the use of organic matter, by growing cover crops, by contour discing, by terracing, by deep plowing and by the use of sod strips.[2]

[2] Clyde, A. W. Terracing to reduce erosion. Ext. Ser. Iowa State College, Ext. Bul. 172. 1931.

INDIVIDUAL SOIL TYPES IN BUTLER COUNTY[3]

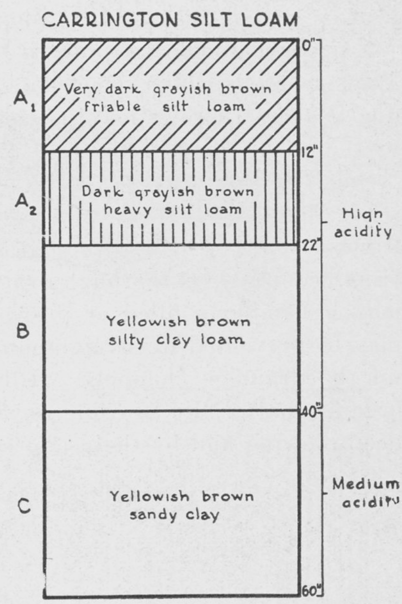
There are 28 soil types in the county, and these with the shallow phase Tama silt loam and the areas of meadow and peat and muck make a total of 31 separate soil areas. They are divided into four groups according to their origin and location—drift soils, loess soils, terrace soils and swamp and bottomland soils.

DRIFT SOILS

There are 14 drift soils, classified in the Carrington, Clyde, Floyd, Dickinson, Dodgeville and Lindley series. Together they cover 71.6 percent of the total area.

Carrington Silt Loam (83)

The Carrington silt loam is the largest drift soil and the largest type in the county, covering 31 percent of the total area. It occurs in extensive areas on the uplands in all parts of the county, the largest individual areas being found in the northern townships. It occupies the broad, more or less gently rolling uplands between the streams, in association with the smaller areas of other upland types. Through the central part of the county, the type is cut by the flat to depressed, irregular areas of the heavier Clyde soils.



The surface soil of the Carrington silt loam is a mellow friable black silt loam, containing a small amount of sand. At 12 to 14 inches the subsurface soil is lighter in color, more granular and less friable, grading at 18 to 22 inches into a silty clay loam, dark yellowish-brown in color. The subsoil between 2 and 3 feet is yellowish-brown in color and in some places faintly stained with gray and rusty brown. In texture it is a silty clay loam, containing some sand and a little gravel. Below 40 inches the subsoil is a sandy clay, somewhat gravelly in small spots, yellowish-brown in color and becoming mottled at the lower depths.

The soil is generally rather uniform, but there are some variations in the different areas. In the northern half of the county much of the soil has a highly plastic mottled subsoil at a depth of 30 inches, which is heavier and more compact and impervious than the typical soil. In some of the more rolling areas, the black surface soil has been washed to the foot of the slopes. Areas of other soil types, too small to show on the map, are included with the type; areas of other Carrington types and of Floyd and Dickinson soils may thus be

3 The descriptions of the individual soil types given in the Bureau of Soils report have been closely followed in this section of the report.

included. In northwestern Bennezette Township, the spots of Floyd silt loam in the type are numerous, and boundary lines between the two types are particularly difficult to place. In this section the soil is much less rolling than typical, and in places it is almost flat.

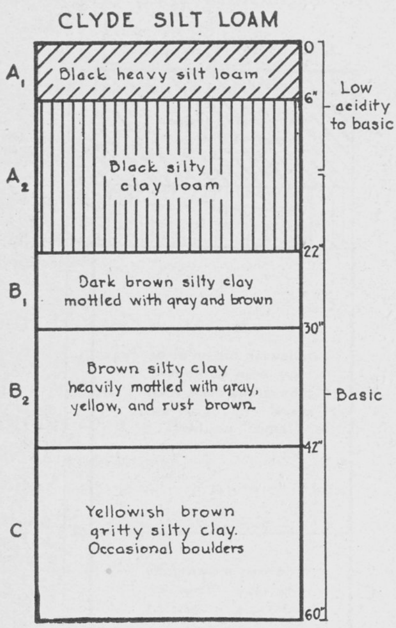
In topography the Carrington silt loam is gently undulating to slightly rolling in typical areas. Sometimes there are more nearly flat areas and occasionally strongly rolling areas. The drainage of the type as a whole is good.

Practically all the Carrington silt loam is under cultivation and well suited for cultivated crops. General farm crops are grown. Corn yields about 40 bushels per acre, with yields sometimes as high as 75 bushels; oats and barley yields average about 35 bushels; wheat yields about 30 bushels, and good hay yields are secured.

The experiments discussed earlier have indicated the soil treatments which will prove of value on this soil. Farm manure brings about large increases in crops. Lime is needed, especially for legumes, as the soil is strongly acid in reaction. The use of a phosphate fertilizer may prove distinctly beneficial on this soil for general farm crops. Either rock phosphate or superphosphate, applied with manure and limestone as basic treatments, may bring about distinctly profitable crop increases.

Clyde Silt Loam (84)

The Clyde silt loam is the second largest drift soil and the second largest type in the county, covering 16 percent of the total area. It occurs extensively in all parts of the county, usually in small narrow strips along the upland drainageways and slopes. Wider areas are found along some of the streams and intermittent drainageways. A few areas occur on flat uplands as depressions without apparent drainage. The largest individual areas occur in northern Pittsford and southern Bennezette townships in the western part.



The surface soil of the Clyde silt loam to a depth of 4 to 6 inches is an intensely black heavy silt loam. To a depth of 20 to 24 inches the soil is a silty clay loam, moderately plastic and less friable. The subsoil to a depth of 30 inches is a dark grayish-brown heavy plastic silty clay, mottled with spots of gray, yellow and rusty brown. From 30 to 42 inches there are more mottlings of gray, yellow and brown. Below 42 inches the subsoil is usually a more gritty silty clay loam and may contain sandy or gravelly material in pockets or thin layers. Boulders occur in the soil and on the surface.

There are some variations from the typical soil in the different areas mapped. A silty clay loam surface soil occurs in some small spots. In a few places a thin layer of black muck occurs on the surface to a depth of 2 inches. The muck areas are found in the poorly drained sections of the type, which are generally water-logged. In other areas a so-called alkali coating has formed on the surface. This has not affected the surface soil to any considerable depth, and the subsoils are all low in lime. These so-called alkali spots are more common in the western part of the county. The subsoils vary considerably in content of sand and gravel, and in some areas the subsoil at 3½ or 4 feet becomes sandy and gravelly and is loose and porous. On the narrower strips of the type in the upland swales, the sandy or gravelly subsoil occurs only in small areas, but over the wider areas it is fairly general. In some of the larger areas the surface soil and subsoil are more silty than typical.

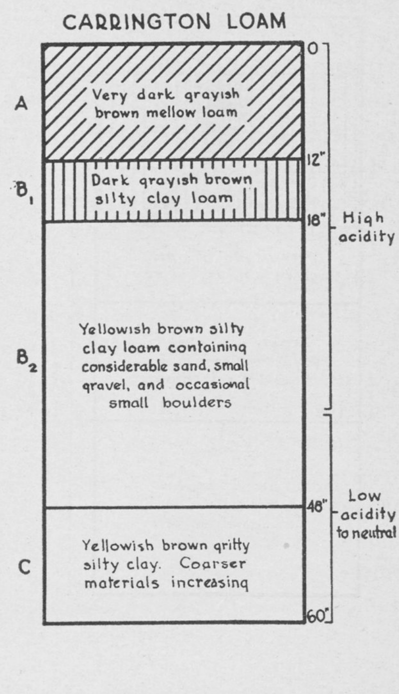
In topography the Clyde silt loam is level to flat or depressed and drainage is very poor. The heavy textured impervious subsoil conditions, along with the flat to depressed topographic position, account for the poor drainage.

Most of the areas in Clyde silt loam are in pasture or wild hay. Drainage is necessary before cultivated crops can be grown. When well-drained, general farm crops would do well. The soils are acid and must be limed for legume crops. The use of a phosphate fertilizer would undoubtedly prove of value, and in some areas—especially when the so-called alkali coating appears—muriate of potash might be used with profit.

Carrington Loam (1)

The Carrington loam is the third largest drift soil and the third most extensive soil type in the county. It covers 7.6 percent of the total area. It occurs in extensive areas on the uplands in all parts of the county. The largest areas are found along the east county boundary, on the upland south of Dumont between the Hartgrave and Maynes creeks and at other points on the uplands adjoining the main stream valleys.

The surface soil of the Carrington loam to a depth of 10 or 12 inches is a black or dark grayish-brown loam. At 18 to 22 inches the soil is a silty clay loam, dark yellowish-brown in color. From 2 to 3 feet the subsoil is a yellowish-brown lighter silty clay loam with some stains of gray and rusty-brown. There is some sand and gravel in the soil material at this depth. Below 40 inches there is a sandy clay, occasionally gravelly with small pockets of sand or gravel. The color is a grayish-yellow brown stained with gray, yellow and rusty-brown.



The areas of the type are fairly uniform, but some variations occur. Sometimes there is a thin surface soil on the strongly rolling areas, and on the slopes the yellowish-brown subsoil may be exposed. In some areas there is an abnormally compact subsoil. Occasionally a sandy layer occurs below the subsoil. Thin surface soils occur north of Sinclair and north of Aplington. Areas with compact subsoils are mapped throughout the northern and northeastern parts of the county. Areas having sandy layers below the subsoil are found in Bennezette and Coldwater townships and in other parts of the county in association with the Dickinson soils.

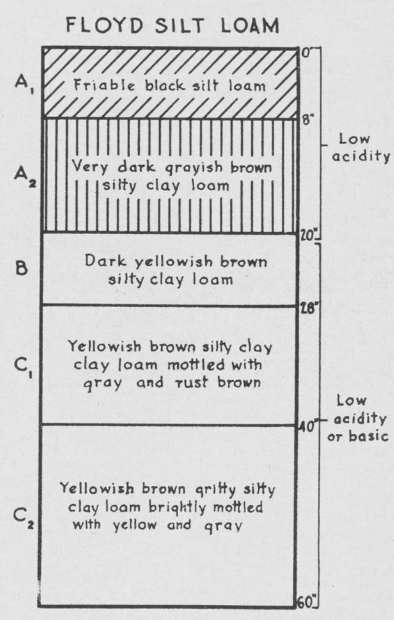
In topography the Carrington loam is gently undulating to rolling or even strongly rolling. Drainage is always good, and on some of the steeper slopes considerable erosion often occurs.

All except a few almost steep areas of the type are under cultivation, and general farm crops are grown. Corn yields 40 bushels per acre. Oats and barley 35 bushels per acre, wheat about 30 bushels, and hay crops give good yields.

The experiments discussed earlier in this report have indicated the value of certain soil treatments. Farm manure gives large crop increases. Lime has a large beneficial effect, especially for legumes. Phosphate fertilizers are effective, and their use is recommended for general farm crops.

Floyd Silt Loam (198)

The Floyd silt loam is the fourth largest drift soil and the fourth largest type in the county. It covers 6.6 percent of the total area. It occurs mainly on gradual slopes between the Clyde and the Carrington soils. The largest areas are found on the flat or very slightly undulating uplands and on the slopes to the drainageways, east of Allison through West Point Township and over much of Bennezette Township. It is the principal soil on the upland in the northwestern part of Monroe Township, lying between the higher uplands to the south and the small creek bottoms on the north.



The surface soil of the Floyd silt loam is a mellow friable black silt loam to a depth of 6 to 8 inches. Below that point it becomes heavier textured and moderately plastic when wet, but friable and crumbly when dry. At 20 inches the color becomes a dark yellowish-brown, stained with some gray and rusty brown, and the texture is a silty clay loam. Below 28 inches the color becomes a lighter yellowish-brown with more mottlings of gray and rusty-brown. Below 40 inches the color is yellowish-brown, more brightly mottled and the texture is a gritty silty clay loam or sandy clay. Boulders occur through the soil and on the surface. Small spots of other soils are occasionally included with the Floyd areas, because of small extent. In general, however, the areas are rather uniform for the type.

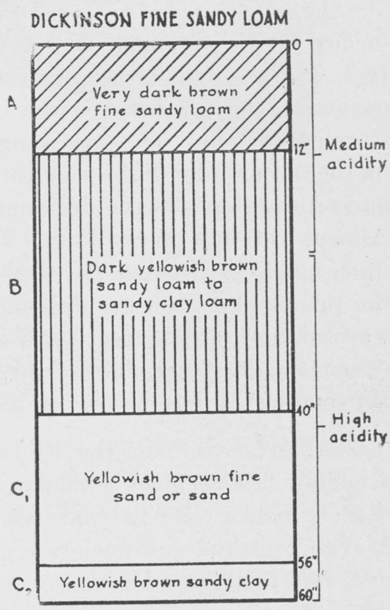
In topography the Floyd silt loam is slightly sloping to flat and the natural drainage is likely to be poor. Tiling is needed for the best crop growth.

Practically all of the type is cultivated, and general farm crops are grown. Corn yields 45 bushels per acre on the average and small grains about 30 bushels per acre. The small grain crops sometimes produce too rank a growth of straw and are likely to lodge. This accounts for the low average yields. Clover and timothy yield 2 to 2½ tons per acre and alfalfa 2½ to 3 tons.

The Floyd silt loam needs adequate drainage in all areas not artificially drained if it is to be made satisfactorily productive. Then it will be benefited by normal additions of farm manure, the use of limestone to correct the acidity of the soil and the use of a phosphate fertilizer.

Dickinson Fine Sandy Loam (175)

The Dickinson fine sandy loam is the fifth largest drift soil covering 4.1 percent of the total area. It occurs on the uplands adjacent to the main stream valleys and seldom extends back on the uplands more than half a mile. The largest area is southeast of Clarksville on the north side of Shell Rock River.



The surface soil of the Dickinson fine sandy loam is a moderately loose and porous very dark brown or black fine sandy loam, extending to a depth of 12 inches. Here the soil becomes more brownish, heavier textured and less porous. Down to 40 inches the soil is somewhat loose and porous, but heavy enough to be slightly sticky when wet. It approaches a sandy clay in texture. In color it is a deep brown. Below 40 inches it is a lighter yellowish-brown or pale yellow, very loose and porous fine sand or sand. Sometimes pebbles, gravel or coarse sand occur. Below this porous layer, which is variable in thickness, the soil is a heavy sandy clay or silty clay. Some boulders occur in the soil and on the surface.

Small areas of the sandy loam, loamy fine sand, sand and loam are included with the type. They are too small to separate. Sometimes the surface soil is a loamy fine sand and the subsoil a heavier sandy texture between 25 and 36 inches. In some areas the heavy sandy clay or silty clay substratum lies 3 or 4 feet below the surface. On the more rolling areas the surface soil is lighter in color and shallower than typical.

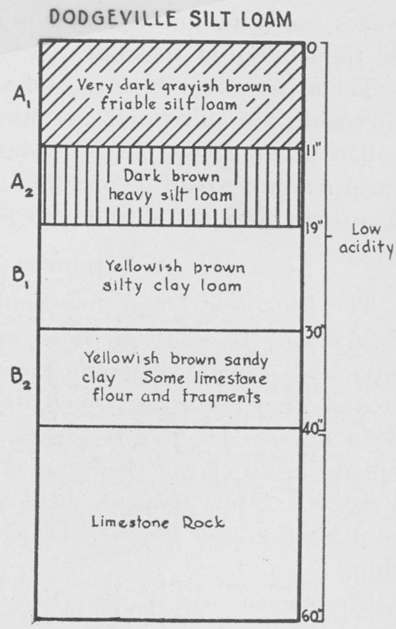
In topography the Dickinson fine sandy loam is gently rolling, and there are few steep slopes. Drainage of the type is good to excessive. The supply of moisture is adequate for crops, however, except in abnormally dry seasons.

The type is mainly cultivated. A small area, along the valley bluffs is in woodland pasture. Corn yields 25 to 30 bushels per acre on the average and small grains 20 to 25 bushels per acre. Rye is the best of the small grains for this soil. Red clover and alfalfa do fairly well in favorable seasons. Potatoes yield well on the type.

The chief need of the Dickinson fine sandy loam is for organic matter, and it will be benefited materially by liberal applications of farm manure or the turning under of legumes as green manures. The soil is acid and must be limed for legume growth. The use of a phosphate fertilizer is desirable, and superphosphate will undoubtedly prove of value for general farm crops.

Dodgeville Silt Loam (204)

The Dodgeville silt loam is the sixth largest drift soil, covering 1.6 percent of the total area. It occurs in areas of varying size, chiefly in the northern part of the county. The largest are found along Coldwater Creek, near Packard, Greene and Clarksville and along a branch of Shell Rock River in Fremont and Butler townships. Small areas occur near Austinville along Beaver Creek.



The Dodgeville silt loam surface soil to a depth of about 11 inches is a very dark grayish-brown or almost black friable silt loam. Below this point and to a depth of 19 inches there is a friable dark brown heavy silt loam. From 19 to 30 inches there is a deep yellowish-brown silty clay loam which when wet is slightly sticky. Below 30 inches there is a sticky, yellowish-brown sandy clay about 6 inches thick, underlaid by a grayish-yellow or bright yellow limerock flour of varying texture. The limerock lies just below this layer. The average depth of the soil to the rock is 44 inches.

In some spots, the underlying bed rock is exposed, chiefly on the slopes. The soil covering the rock ranges in thickness from less than 1 foot to 6 feet. The thinner soil coverings are more sandy in texture. Near Austinville the areas are lighter colored than typical and more silty in the subsoil. In many places the layer of soil directly overlying the bedrock consists of a sticky, coarse loose sand.

About one-fourth of the Dodgeville silt loam is cultivated to grain and hay crops, one-eighth is in woodland and the remainder is in permanent pasture or brush land. On the steeper slopes the land is used for pasture.

When cultivated this soil will be benefited by liberal applications of farm manure. Liming is needed for legume crops, and a phosphate fertilizer would undoubtedly prove of value. Pastures on the type may be improved by discing, reseeding, liming, the use of manure and a phosphate fertilizer.

Clyde Silty Clay Loam (85)

The Clyde silty clay loam is the seventh largest drift soil, covering 1.5 percent of the total area. It occurs in many areas in upland swales and along the intermittent drainageways. Fairly large areas occur in sections 6 and 8 of Monroe Township. Areas occur in Bennezette Township and along the southern county boundary. These areas occupy upland swales.

The surface soil of the Clyde silty clay loam is a black silty clay loam to a depth of 4 or 6 inches. To a depth of 30 inches the soil is a dark grayish-brown heavy plastic silty clay mottled with gray, yellow and rusty-brown. Between 30 and 42 inches the soil is more mottled than the layer above. Below 42 inches the subsoil is a more gritty silty clay loam and contains pockets or layers of sand and gravel.

In some areas there is a 2-inch layer of muck on the surface of the soil. In other areas a so-called alkali coating occurs on the surface, but the effect of this covering is limited to the surface soil, and the subsoils are always acid, containing no lime. Occasionally the subsoil to a depth of 3½ or 4 feet becomes sandy or gravelly and is loose and porous. Boulders occur frequently on the surface of the soil.

The areas of the type in Monroe Township and a few of those in Bennezette Township are cultivated, the other areas being in pasture or hay land. When cultivated, the type needs drainage first of all. Then a small application of farm manure would be of value. Liming is necessary for legumes, and a phosphate fertilizer would undoubtedly prove of value.

Dickinson Loamy Fine Sand (249)

The Dickinson loamy fine sand is a minor type, covering 1.1 percent of the total area. It occurs in small areas, usually on low sandy upland slopes and ridges adjacent to the main stream valleys. A few areas are underlaid by limestone. They occur near Shell Rock in Section 33 of Jefferson Township and in Section 28 of Dayton Township. Other areas occur on knolls or ridges in the upland areas of the Dickinson fine sandy loam between Aredale, Dumont and Bristow. A few areas on small knolls are found in Section 34 of Butler Township, Section 6 of Beaver Township, and sections 25 and 36 of Pittsford Township.

The surface soil of the Dickinson loamy fine sand consists of a very dark grayish-brown or almost black loose porous loamy fine sand to a depth of 15 inches. Between 15 and 27 inches the soil is a brown or dark grayish-brown loamy fine sand or loamy sand. Below 27 inches, the soil is a light yellowish-brown or pale yellow loose and porous sand. In general, the soil and subsoil contain mainly sand, but in some places there are pebbles, some boulders and small rocks. Below 5 or 6 feet there is the heavy sandy clay drift with pebbles, gravel and small rocks.

In some places the surface soil consists of a looser coarser sand than typical. Such areas occur in sections 6 and 36 of Butler Township, Section 1 of Shell Rock Township, Section 2 of Pittsford Township, Section 24 of Coldwater Township, Section 11 of Madison Township, Section 10 of Ripley Township, and Section 16 of Beaver Township. A large area occurs in sections 13, 14, 23 and 24 of Beaver Township. In a few areas there are heavier sandy loam subsoils, and in some cases the heavy silty clay substratum lies at a depth of 2½ or 3 feet. The soil is all excessively drained and it is apt to be drouthy. Drifting of the soil also is likely to occur in some areas.

A small area of the type is in woodland pasture and the forest growth consists of small bur oaks. Most of the soil, however, is under cultivation or in pasture. Yields of general farm crops are likely to be low, and frequently the pastures are thin and poor. The chief need of the soil to be made more productive is for the application of farm manure in liberal amounts or the turning under of a legume as a green manure. The type is acid and needs lime, and the application of superphosphate would undoubtedly prove of value. If truck crops are grown and the soil is well suited to such crops, complete commercial fertilizers might also be used with profit.

Carrington Fine Sandy Loam (4)

The Carrington fine sandy loam is a minor type, covering less than 1 percent of the total area. The largest areas are east of Packard, on the bluffs of the West Fork Cedar River and in the vicinity of Bristow.

The surface soil of the Carrington fine sandy loam is a dark grayish-brown to black loose and porous fine sandy loam to a depth of about 12 to 14 inches. Between 13 to 24 inches the soil is a dark brown fine sandy loam, a little heavier than the surface soil. Below 20 inches the soil is yellowish-brown, faintly stained with gray and rusty-brown and a silty clay loam in texture. Some sand and gravel are found at this depth. Below 40 inches there is a sandy clay somewhat gravelly in spots, friable when dry but plastic when wet. Boulders occur in the soil and at the surface.

As mapped, the Carrington fine sandy loam includes small spots of the Dickinson soils and also areas of other Carrington soils too small to separate. Where the soil is associated with the Dodgeville soils, there is an abnormally compact tough and plastic clay layer in the subsoil. In other areas, there is a less intensely black surface soil, lower in organic matter content than typical. Such areas occur on the elevated bluffs along the stream valleys.

In topography the Carrington fine sandy loam is rolling or gently rolling. There are some steep slopes to the main stream valleys on which the type occurs. Drainage of the soils is excellent everywhere but not excessive.

About one-fourth of the type is in woodland pasture; another fourth is in permanent bluegrass pasture. One-half of the area is cultivated to hay and grain crops. Corn yields about 35 bushels and oats about 30 bushels per acre. Hay crops yield lower than on the heavier textured soils and are more difficult to establish.

The Carrington fine sandy loam needs especially to be built up in organic matter content to be made more productive. Liberal applications of farm manure, and the turning under of legumes as green manures are very desirable. The soil is acid and needs lime especially for legumes. The addition of a phosphate fertilizer would certainly be worth while, and tests of superphosphate are urged.

Dickinson Sandy Loam (199)

The Dickinson sandy loam is a minor type, covering only 0.5 percent of the total area. It occurs in a number of small areas. The larger areas are found in sections 8 and 36 of Butler Township and in Section 25 of Beaver Township. Other areas occur southeast of Packard, west and southwest of Bristow, east and south of Dumont on ridged upland crests adjoining stream valleys and in sections 3, 4 and 10 of Pittsford Township.

The surface soil of the Dickinson sandy loam to a depth of 12 inches is a dark brown to black sandy loam. From 12 to 25 inches the soil is a deep brown sandy clay loam. This layer is thinner than in the Dickinson fine sandy loam and hence the water-holding power of the soil is lower as this is the layer which is chiefly responsible for holding moisture in these soils. Below 25 inches there occurs the light yellowish-brown or pale yellow loose and porous fine sand or sand, typical of the Dickinson subsoils. At lower depths the substratum is a heavy sandy clay or pebbly silty clay. This occurs at 4 or 5 feet in most areas. Boulders occur on the surface and through the soil.

In topography the Dickinson sandy loam is rolling to strongly rolling. It occurs on upland ridges or knolls, which are not steep. Drainage is good to excessive and the soil is apt to be drouthy. There is some drifting of the soils by wind action.

Much of the Dickinson sandy loam supports a scattered growth of oaks and a thin stand of grass. In these areas the surface soil is lighter colored and shallower than typical. In some of these areas the soil is a loamy sand. When cultivated, areas of the type are low in productivity, and crop yields are frequently seriously reduced by drouth.

The chief need of the Dickinson sandy loam, when cultivated, is for organic matter. Liberal applications of farm manure and the turning under of legumes as green manures would be of large value. The soil is acid and needs lime, especially for legumes. The use of superphosphate would certainly help.

Dodgeville Loam (223)

The Dodgeville loam is a minor type, covering only 0.3 percent of the total area of the county. It occurs in a number of small areas mostly on the slopes to the streams. The largest development of the type is in Fremont Township along an intermittent drainage line, the only area not on a rather steep slope to a main stream valley.

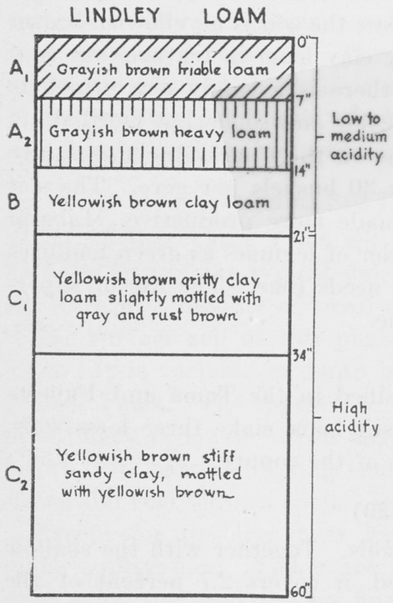
The surface soil of the type is a dark grayish-brown or almost black mellow friable loam to a depth of about 10 inches. Below this point and extending to 19 inches there is a dark brown heavy silt loam. From here to 30 inches the soil is a deep yellowish-brown silty clay loam. The next layer is a sticky yellowish-brown sandy clay about 6 inches thick. The material resting on the limerock is a grayish-yellow or bright yellowish limerock flour of varying texture. The limerock occurs at a depth of 36 to 40 inches. The surface soil contains spots of sandy loam soils which in many places extend to a depth of 2 feet. In many areas the soil resembles the Dickinson and Carrington loams with which it is closely associated.

The soil is mostly in pasture, as it occurs generally on rather steep slopes. The areas in Fremont Township are the exception. They are cultivated. Yields are low, however, and the pasture is poor.

When cultivated the soil needs organic matter in the form of farm manure or leguminous green manures. It is acid and needs lime. It will be benefited by the use of a phosphate fertilizer. Some of the better, less steep pasture areas may be improved by discing, reseeding, liming and fertilization.

Lindley Loam (65)

The Lindley loam is a minor type, covering only 0.2 percent of the total area of the county. It occurs in a number of areas, the largest being found on the bluffs north of Beaver Creek between Sinclair and New Hartford and on a bluff along Shell Rock River near Clarksville. Smaller areas occur in Section 29 of Washington Township, Sections 26 and 27 of Madison Township and Section 24 of Pittsford Township.



The surface soil of the Lindley loam to a depth of about 7 inches is a grayish-brown friable loam. It is underlaid by a grayish-yellow brown heavy loam. At about 14 inches the soil is a yellowish-brown heavy clay loam or silty clay loam which is plastic when wet and quite friable when dry. This layer is about 7 inches thick. Below it there is a more plastic silty clay loam containing some sand and pebbles, and mottled with gray and rusty-brown. Below 34 inches, there is a very mottled yellowish-brown plastic silty clay or sandy clay, which changes very little to a depth of 5 feet.

Practically all of the Lindley loam is in woodland or permanent pasture. If cultivated the soil is subject to serious erosion. It is generally too steep to be cultivated, but if it is plowed it must be protected from erosion and built up in organic matter by the use of farm manure or green manures.

Dickinson Loam (174)

The Dickinson loam is a minor type, covering only 0.2 percent of the total area. It occurs in a number of areas, chiefly in Coldwater and Dayton townships. The most typical areas are found in cuts where gravel pits are opened for road use. The gravelly subsoil may not extend much beyond the borders of the pits.

The surface soil of the type to a depth of 10 inches is a gritty rather heavy loam, dark grayish-brown to black in color. Below this layer there is a heavier loam or clay loam layer, dark brown in color and averaging 8 inches in thickness. The next layer of 6 or 7 inches is a dark reddish-brown, loose crumbly, clayey gravel layer which is very porous, resting on the loose, very porous coarse sand and gravel subsoil. Small somewhat clayey spots occur in the subsoil. Boulders occur through the soil and on the surface.

The type is unimportant agriculturally. The areas are small and are farmed with the adjacent types. Yields are low as the soil is drouthy. When farmed, the soil needs organic matter and should receive liberal applications of farm manure or legumes as green manures. It is acid and must be limed. It would also respond to the addition of superphosphate.

Carrington Sandy Loam (3)

The Carrington sandy loam is a minor type, covering only 0.1 percent of the total area of the county. It occurs only along the eastern county boundary.

The surface soil to a depth of about 12 inches is a dark grayish-brown to black sandy loam. From 12 to 24 inches there is a dark brown sandy loam, a little heavier than the surface soil. Between 2 and 3 feet the soil is a yellowish-brown stained with gray and rusty-brown. It is a silty clay loam in texture, but contains some sand and gravel. Below 40 inches there is a sandy clay which is somewhat gravelly in spots, yellowish-brown in color and somewhat mottled.

Crop yields on the type are about the same as on the Carrington fine sandy loam, corn averaging about 35 bushels and oats 30 bushels per acre. The soil needs organic matter, especially if it is to be made more productive. Liberal applications of farm manure and the turning under of legumes as green manures would be of large value. The type is acid and needs lime. The use of superphosphate would also undoubtedly prove of value.

LOESS SOILS

There are two loess types in the county classified in the Tama and Fayette series, and these with the shallow phase Tama silt loam make three loess soils. Together they cover 3.3 percent of the total area of the county.

Tama Silt Loam (120)

The Tama silt loam is the larger of the loess soils. Together with the shallow phase, which is much less extensively developed, it covers 2.7 percent of the county. There are several areas of the type, the largest occurring between Aplington and Kesley and near Dumont. The other areas occupy upland crests in sections 23 and 24 of Albion Township.

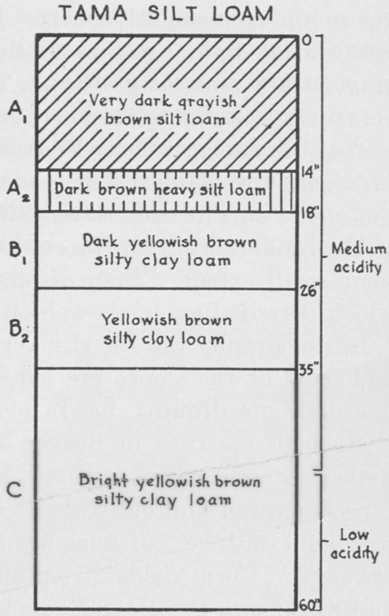
The surface soil of the Tama silt loam is a mellow, friable silt loam, dark grayish-brown to black in color and usually extending to a depth of about 14 inches. From this point to a depth of 24 inches there is a dark brown heavy silt loam less mellow and friable than the layer above, becoming lighter in color with increasing depth. At about 26 inches the soil is a dark yellowish-brown heavy silt loam. Below 36 inches and extending to a depth of 4 or 4½ feet the soil is a more friable, lighter yellowish-brown silt loam. In the lower part of this subsoil there are faint gray and yellow stains and rusty brown and black spots.

On the more rolling uplands having steeper slopes, there is a thinner surface soil and in small strips or spots the brownish-subsoil is exposed. Larger areas eroded to this extent are mapped as the shallow phase of the type. On the more gentle slopes, or level areas, the surface soil is thicker and the subsoil is heavier.

In topography the Tama silt loams range from very gently rolling to rolling. Natural drainage is good and only on the more rolling lands is the surface wash at all rapid.

Practically all the type is cultivated. The yields are similar to those secured on the Carrington silt loam. Corn yields 40 bushels per acre, on the average, oats and barley 35 bushels per acre. Good yields of hay are secured.

The Tama silt loam may be increased in productivity by the application of farm manure. It is acid and the use of lime to correct the acidity is necessary, especially for the best growth of legumes. The soil will undoubtedly respond to applications of a phosphate fertilizer, and tests of rock phosphate and superphosphate are recommended.



Tama Silt Loam (shallow phase) (143)

The shallow phase Tama silt loam is minor in occurrence, covering less than half the area of the typical soil. It occurs in association with the typical Tama silt loam in a number of small areas.

The surface soil of this phase is a dark grayish-brown to black mellow silt loam. It is variable in depth but much shallower than the surface soil of the typical Tama. The subsurface soil is a dark brown heavy silt loam, changing into a dark yellowish-brown heavy silt loam. The subsoil is a lighter yellowish-brown silt loam containing some fine sand and having faint gray and yellow stains and rusty-brown spots. In many areas the subsoil is exposed on the slopes.

Except for the area near Kesley which is largely wooded, the land is all under cultivation. Yields are lower than on the typical soil and about the same as on the Fayette very fine sandy loam. Corn yields 25 or 30 bushels per acre, oats and barley about 30 bushels per acre and wheat and rye 15 or 20 bushels. The soil needs organic matter and will be benefited by an application of farm manure. Lime is necessary as the soil is acid. The use of superphosphate would also undoubtedly prove of value.

Fayette Very Fine Sandy Loam (250)

The Fayette very fine sandy loam is a minor type, covering only 0.6 percent of the total area. It occurs entirely in strips on rather elevated uplands in Beaver, Albion, Madison and Washington townships.

The surface soil of the type is a very smooth, mellow very fine sandy loam, dark grayish-brown or dark brown in color, and extending to a depth of 7 to

17 inches. The subsurface soil is a very friable silt loam, light yellowish-brown in color, tinged with gray. Between 17 and 28 inches the material is a heavy silt loam or very fine sandy clay loam, yellowish-brown in color. From 28 to 40 inches there is a lemon-yellow or light yellowish-brown, more friable very fine sandy loam, slightly gritty. Below 40 inches there is a very friable very fine sandy loam, lighter yellow or light yellowish-brown in color with stainings of gray, yellow and rusty-brown. There is very little change in the soil until the heavy silty clay substratum is encountered at a depth of 6 to 15 feet.

There are some variations from the typical soil in different areas. The surface soil is sometimes a fine sandy loam and sometimes a silt loam. On some slopes the surface soil is very thin because of extensive erosion. Small areas of the Lindley loam on the eroded slopes are included with the type, because of their small extent. There is one area in Section 27 of Madison Township in which there is lime in the subsoil at a depth of 2 to 3 feet.

In topography the Fayette very fine sandy loam is rolling or sharply rolling, and most of the slopes are subject to erosion. A few are gullied. The type is usually not drouthy, but in some cases crops suffer in dry seasons.

Much of the type in Beaver Township is in woodland, with a rather sparse timber growth and is utilized for pasture. In Albion Township most of the type is cleared and cultivated. The other areas in the county are generally in woodland pasture, but some are cultivated. Crop yields on the cultivated areas are good. Corn yields 25 or 30 bushels per acre, oats and barley 30 bushels and wheat and rye 15 or 20 bushels.

The Fayette very fine sandy loam will be improved materially for the production of general farm crops by the use of farm manure in liberal amounts, the turning under of legumes as green manures, the addition of lime to correct acidity and the application of a phosphate fertilizer.

TERRACE SOILS

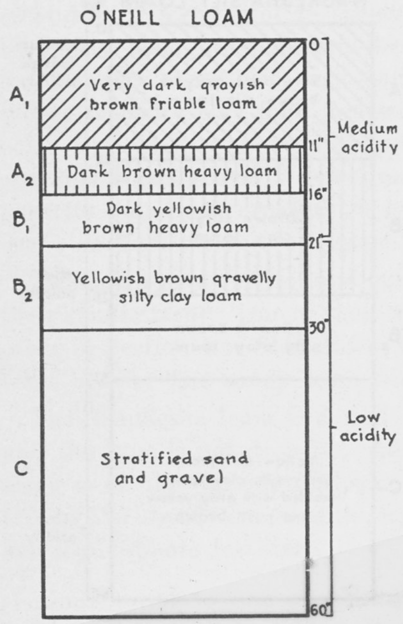
There are 7 terrace soils in the county classified in the O'Neill, Waukesha, Bremer, Fargo and Millsdale series. Together they cover 12.9 percent of the total area.

O'Neill Loam (108)

The O'Neill loam is the largest of the terrace soils, covering 4.3 percent of the county. It occurs on terraces well above the first bottoms, and most of the areas are found on the higher terraces along the Shell Rock River.

The surface soil of the type is a very dark grayish-brown or almost black friable loam, extending to a depth of about 11 inches. From 11 to 16 inches the soil is a heavier dark brown loam which becomes a more coarsely gritty dark yellowish-brown heavy loam at a depth of 16 inches. At 21 inches there is a yellowish-brown gravelly loam containing some clay. At 2 feet there is a loose coarse sand and gravel, pale yellow or grayish-yellow to reddish or yellowish-brown. This layer continues as beds of sandy gravel to considerable depths.

There are some variations from the typical soil. In places the layer between the black surface soil and the loose gravel subsoil is somewhat mottled, heavier and more retentive of moisture than the typical. Such areas are in the lower parts of the terraces where drainage is slow. In other areas the subsoil above the gravel is lighter in texture and more porous. This subsoil is usually associated with the lighter textured surface soil, heavier than the sandy loam, but lighter than most of the loam. A few small areas of silt loam are included with the type because of their small extent. These occur near Greene in sections 1 and 18 of Dayton township, in sections 1 and 3 of Fremont townships and in sections 14 and 32 of Shell Rock Township. The soil here is a little less drouthy and more productive than the typical loam. The surface soil in these included areas is deeper as well as heavier than the typical soil.



The O'Neill loam is excessively drained and is likely to be drouthy. Practically all of it is in grain, hay and pasture, but owing to its drouthiness, crop yields are lower on the average than on the Carrington loam. In favorable seasons very good yields are obtained. Corn yields 25 bushels and oats 30 bushels per acre. Potatoes do well, and the hay crops give good yields in normal seasons.

The type is chiefly in need of organic matter to be made more productive. Liberal applications of farm manure would be of large value, and the turning under of legumes as green manures would be very much worth while. Liming is necessary to correct the acidity of the type, and the use of a phosphate fertilizer would undoubtedly help. Tests of superphosphate are recommended.

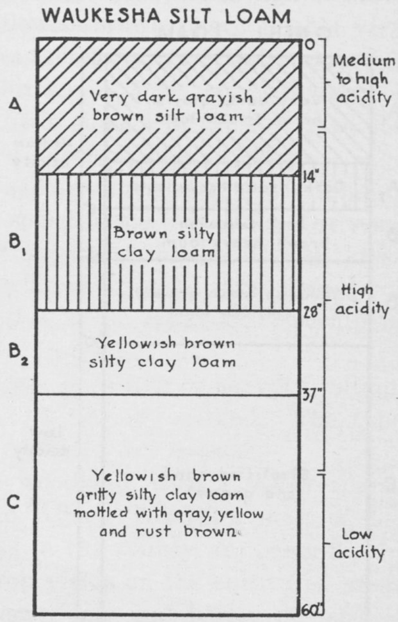
Waukesha Silt Loam (75)

The Waukesha silt loam is the second largest terrace soil, covering 3.3 percent of the total area. The type occurs on terraces, the largest areas appearing along the Shell Rock River and its tributaries, Flood and Coldwater creeks. Several bodies occur in the valley of Beaver Creek and in the valley of the West Fork Cedar River and its tributaries.

The surface soil of the Waukesha silt loam is a mellow very dark grayish-brown silt loam, extending to about 14 inches. From this point to a depth of 28 inches, there is a dark brown silty clay loam. From 28 to 37 inches there is a very dark yellowish-brown silty clay loam. Below 37 inches the silty clay loam becomes gritty and somewhat gravelly in places and the color is lighter, being yellowish-brown with gray, yellow and rusty-brown stains.

Throughout the type there are small areas which differ from the typical. In an area in Section 4 of Shell Rock Township and in one in Section 34 of Butler Township, there is an extremely smooth, fine textured soil with no grit or sand. An area near Clarksville has a gravelly sandy porous substratum below 4 or 5 feet. Here the subsoil above the substratum is heavier than typical. In some cases the black surface soil extends to a depth of 24 to 30 inches.

In topography the soil is level to very gently sloping. Practically all of it is cultivated. It is not drouthy and drainage is adequate. Crop yields are much the same as on the Carrington silt loam.



The Waukesha silt loam may be made more productive by the usual treatments with farm manure and the use of legumes as green manures. It is acid in reaction and is in need of lime. It would probably respond to the application of a phosphate fertilizer, and tests of rock phosphate and superphosphate are advised.

O'Neill Sandy Loam (126)

The O'Neill sandy loam is the third terrace type, covering 2.6 percent of the total area. It occurs on terraces mainly near Clarksville and Shell Rock and along the West Fork Cedar River in the southeastern part of the county. There are small areas in other parts.

The surface soil of the O'Neill sandy loam is a dark grayish-brown sandy loam to a depth of 12 or 14 inches. It is underlaid by a yellowish-brown or brown sandy loam which is nowhere much heavier than the surface soil and in many places much lighter and more porous. The loose porous sand and gravel substratum characteristic of the O'Neill soils lies at a depth of about 2 feet below the surface. In some areas the surface soil is a loamy sand about 12 inches thick and the subsoil a sandy loam. These areas are too small to map separately. The type is very porous and drouthy. When dry the surface soil is likely to drift in exposed uncovered areas, such as newly-planted seedbeds.

The type is all in cultivation, but yields are low because of the drouthiness of the soil. The needs are first for organic matter, using farm manure and legumes as green manures to increase the water-holding power of the soil and make it less drouthy. It is acid and needs lime if legumes are to be grown, and it will undoubtedly respond to a phosphate fertilizer such as superphosphate. Alfalfa and sweet clover are good deep-rooted legumes to grow to hold the soil from blowing. Rye and buckwheat are also grown in the soil successfully and serve to hold it. Potatoes do well. All these crops are benefited by fertilization of the soil.

Waukesha Loam (60)

The Waukesha loam is the fourth terrace type, covering 1.6 percent of the total area. It occurs on high terraces the largest areas appearing near Packard along Shell Rock River and Floyd Creek, south of Eleanor along Beaver Creek and in Madison and Ripley townships along the West Fork Cedar River and Maynes Creek.

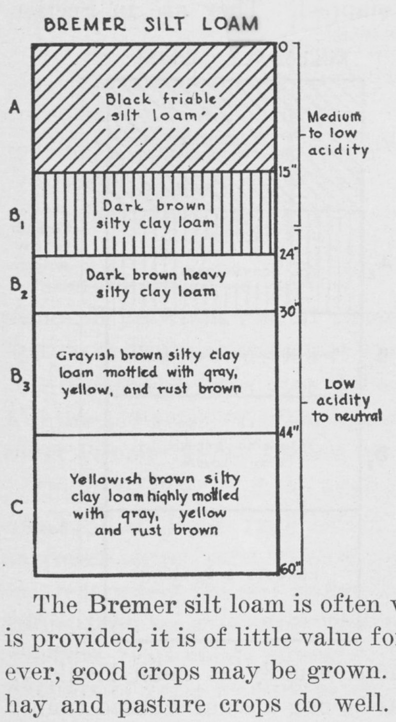
The surface soil of the Waukesha loam is a very dark grayish-brown loam, extending to a depth of 14 inches. From 14 to 28 inches there is a dark brown silty clay loam heavier than the surface soil, containing less sand. From 28 to 37 inches there is a very dark yellowish-brown silty clay loam. Below 37 inches the silty clay loam becomes gritty and gravelly and yellowish-brown in color with gray, yellow and rusty-brown stains. The subsoil in many places contains some gravel. Sometimes below 4 feet there is a somewhat porous gravelly soil. Some areas of the type have a lighter textured subsoil. These areas occur on high terraces along the Shell Rock River.

Two small areas of the fine sandy loam are included with the type because of their small extent. One of these areas is in Section 8 of Butler Township and the other in Section 4 of Shell Rock Township. The subsoil in these areas is a somewhat heavier fine sandy loam with good moisture-holding capacity.

The Waukesha loam is a well drained soil, but the drainage is not excessive and the type is not drouthy. Most of it is cultivated, and yields are much the same as on the Carrington loam. Like that type, it will be made more productive by the use of farm manure, leguminous green manures, lime to correct acidity and a phosphate fertilizer.

Bremer Silt Loam (88)

The Bremer silt loam is a minor type, covering 0.9 percent of the total area.



It occurs on flat somewhat depressed rather poorly drained terraces. The larger areas are found near Shell Rock along the West Fork Cedar River and its main tributaries in Jefferson and Shell Rock townships and along Beaver Creek near Parkersburg and New Hartford.

The surface soil of the type is a black friable silt loam to a depth of 15 inches. Here there is a slightly grayish heavier silt loam or silty clay loam which becomes a rather heavy silty clay loam at 24 inches with more of a grayish-color. At 30 inches there is a mottled lighter-colored silty clay loam containing more sand than the layers above. This layer continues to a depth of 44 inches, where there is a lighter, yellowish-brown or grayish-brown material, lighter in texture.

The Bremer silt loam is often very poorly drained and until adequate drainage is provided, it is of little value for cropping or for pasture. After drainage, however, good crops may be grown. Small grains are likely to lodge, but corn and hay and pasture crops do well. Liming is necessary for the legume crops, as the type is acid and the use of a phosphate fertilizer would certainly increase the yields of general farm crops.

Fargo Silty Clay Loam (109)

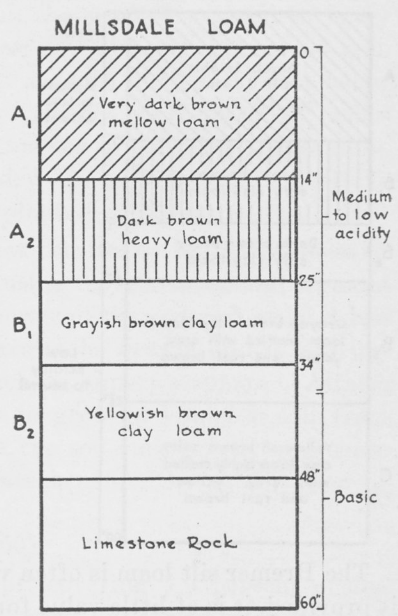
The Fargo silty clay loam is a very minor type, covering only 0.1 percent of the total area. Only 3 small areas are mapped. The largest is in Section 18 and the others are in sections 27 and 34 of Washington Township.

The surface soil of the type to a depth of about 18 inches is a black friable crumbly silty clay loam. It is underlaid by silty clay, heavier than the soil above, not so dark in color and stained with yellow, gray and rusty brown. At a depth of 28 inches there is a gritty silty clay containing some pebbles and mottled yellow, brown, gray and rusty-brown in color. At about 34 inches the material is a grayish or light-yellowish-gray mottled silty clay, containing some fine sand and lime-coated pebbles and concretions. The soil is usually basic in reaction in the surface soil and strongly basic throughout the subsoil.

Most of the areas of the Fargo silty clay loam are in grain and hay crops, but yields are usually poor because of lack of adequate drainage. When thoroughly drained, good yields of corn are secured and hay crops do well. Small grain crops are likely to lodge. The soil will be benefited by applications of a phosphate fertilizer in cultivated areas, after drainage conditions have been made adequate. Rock phosphate or superphosphate may be used to advantage.

Millsdale Loam (188)

The Millsdale loam is a minor type, covering only 0.1 percent of the total area. Only four small areas of the type are mapped. They are in Section 35 of Pittsford Township, Section 2 of Coldwater Township, Section 35 of Dayton Township and Section 28 of Butler Township.



The surface soil of the type is a very dark brown or black mellow loam or heavy fine sandy loam about 14 inches in depth. It is underlaid to a depth of about 25 inches with a very dark brown loam which is lighter than the surface soil and grayish in color. Between 25 and 34 inches there is a dull grayish-brown clay loam which is somewhat sticky and plastic when wet but compact when dry. From 34 to 41 inches there is a dark yellowish-brown clay loam containing some coarse sand. Below 41 inches the material is a loose porous light yellowish-brown sandy loam. From 45 to 50 inches there is a very plastic layer resting on the limerock.

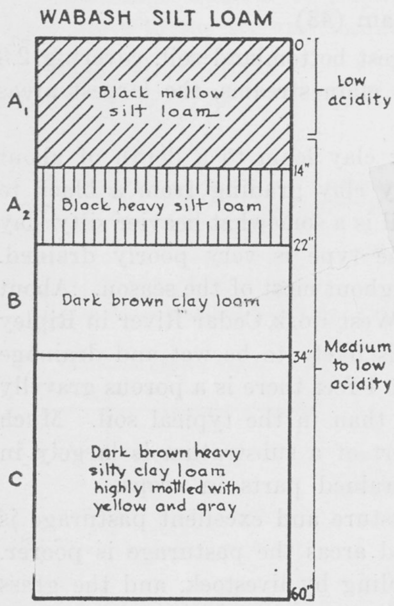
The Millsdale loam occurs on the high terraces, usually as small knolls or ridges. Most of the type is in pasture, some areas having a scant stunted timber growth. If cultivated, the soil would be made more productive by applications of farm manure, the use of lime to correct acidity and the addition of a phosphate fertilizer. Pasture areas may be improved by discing, reseeding, liming and fertilization.

SWAMP AND BOTTOMLAND SOILS

There are five bottomland soils in the county, classified in the Wabash, Cass and Lamoure series, and these with the areas of meadow and muck and peat make a total of seven areas of bottomland.

Wabash Silt Loam (26)

The Wabash silt loam is the largest of the bottomland soils, covering 48 percent of the total area. It is the fifth largest soil type in the county. It occurs in the bottoms along the main streams. The largest areas are found along the West Fork Cedar River in Ripley, Madison and Pittsford townships and along Beaver Creek between Parkersburg and Sinclair. Several large areas occur near Packard in the wider bottoms of the Shell Rock River. The remaining areas are narrow strips along the streams.



The surface soil of the Wabash silt loam to a depth of about 14 inches is a black mellow friable silt loam. From 14 to 22 inches the soil is a black heavy silt loam. Between 22 and 34 inches there is a plastic very dark brown or black silty clay loam. Below 34 inches the soil is a heavy silty clay loam, very dark brown in color and highly mottled. The soil changes little between 3 and 6 feet.

The type varies considerably in different areas. There are small spots of loam, silty clay loam and fine sandy loam. In many places in the areas east of Parkersburg along Beaver Creek and near Dumont, there is a deep substratum of loose gravel at a depth of 4 or 5 feet.

In topography the type is level or very gradually sloping. Where the land is protected from overflow, drainage is fairly good. Only in a few places does water remain on the surface of the soil for any extended periods.

The greater part of the Wabash silt loam in the wider bottoms is cropped to corn. Small grains rank second, pasturage third and hay crops fourth. On the narrower strips, corn, small grains and hay are grown only in small patches or on areas where the soil makes up parts of fields on terraces or uplands. Small grains tend to grow rank and lodge. When well drained and protected from overflow, crop yields on the type are excellent. It is of value to apply small amounts of farm manure to the type, especially when newly drained. The soil is acid and needs lime, especially for legume growth. It will be benefited also by the application of a phosphate fertilizer.

Meadow (20)

The area of meadow is rather large, amounting to 3.2 percent of the total area of the county. It occurs in many areas along the main stream channels which are cut with old channels, sandy ridged banks and strips of mud flats, and the soil conditions are extremely variable. Small spots of practically every soil type from sand to clay of the Wabash, Cass and Lamoure series may be found.

All the areas of meadow are pastured except for a few small patches, or spots which are cultivated. Some timber growth occurs along the channels of the streams. A few small swampy areas have a dense brushy growth of alder and willow. The land is frequently overflowed. The pasture value of the areas is high.

Wabash Silty Clay Loam (48)

The Wabash silty clay loam is the third largest bottomland soil, covering 2.3 percent of the total area. It occurs along the main streams, the largest areas occurring along the West Fork Cedar River.

The surface soil of the type is a black silty clay loam to a depth of about 12 inches. Below this point it becomes a silty clay grading from a black to a very dark brown in color. Below 2 feet the soil is a somewhat heavier silty clay to clay, and the color is a little lighter. The type is very poorly drained. Some areas remain in a swampy condition throughout most of the season. About 3 square miles of this swampy soil lie along the West Fork Cedar River in Ripley and Jefferson townships. In general, the soil is likely to be wet and drainage is very slow. In some places at a depth of about 4 feet there is a porous gravelly or sandy substratum where drainage is better than in the typical soil. Much of the soil north of Dumont which has this sort of a substratum is largely in pasture with smaller patches in the better drained parts in crops.

Most of the Wabash silty clay loam is in pasture and excellent pasturage is usually provided. On the more poorly drained areas the pasturage is poorer. The surface is hummocky as a result of trampling by livestock, and the grass bunchy. Many bare muddy spots occur in the pastures. A few patches of the type, sufficiently well drained for cropping, produce excellent yields of general farm crops. The soil must be plowed at the right time, when it is not too wet or too dry, in order to provide a fine crumbly seedbed. It will be benefited by small amounts of farm manure. The type is acid and needs lime, especially for legumes. It would also be benefited by the addition of a phosphate fertilizer.

Wabash Loam (49)

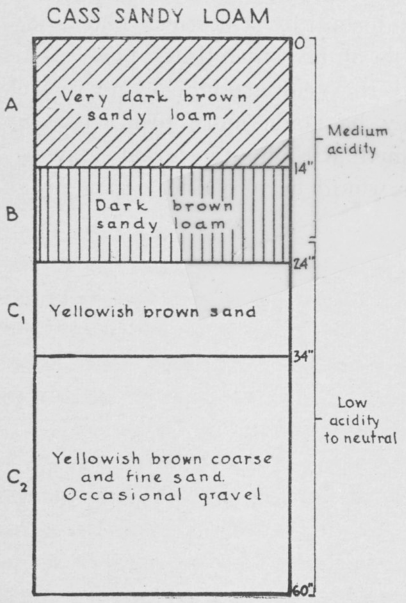
The Wabash loam is the fourth largest bottomland soil, covering 1.5 percent of the total area. It occurs on the bottoms in the higher areas, in many places the first rise from the meadowland along the stream channels. Many small areas of the type occur.

The surface soil of the Wabash loam consists of a black friable rather gritty loam, extending to a depth of about 12 or 14 inches. Below this point and continuing to about 28 inches there is a very dark brown or black heavy loam which is underlaid by a subsoil and substratum which is a heavier loam to silty clay loam or clay loam, the color becoming somewhat lighter at the lower depths and gradually heavier in texture. Small spots of fine sandy loam, silt loam, silty clay loam and clay loam are included with the type.

Most of the type is in pasture land. Grasses do well and the soil has a high pasture value. Few areas are of sufficient size for cropping. The drainage of the type, however, is good. With protection from overflow it can be successfully cultivated. In such cases it would be benefited by small amounts of farm manure, the use of lime to correct acidity and the application of a phosphate fertilizer.

Cass Sandy Loam (19)

The Cass sandy loam is a minor type, covering 0.2 percent of the total area. It occurs in a number of small areas of well-drained, slightly ridged bottomlands close to the stream channels. The larger areas lie along the West Fork Cedar River and Beaver Creek in sections 9, 10, 11, 34, 35 and 36 of Beaver Township and in sections 35 and 36 of Albion Township and along the Shell Rock River in sections 34 and 35 of Dayton Township.



The surface soil of the Cass sandy loam to a depth of 14 inches is a very dark brown moderately loose sandy loam. Between 14 and 24 inches the soil is a moderately loose and porous dark brown sandy loam, a little heavier than the layer above. From 24 to 34 inches there is a brown or dark yellowish-brown very porous loose sand containing some gravel. Below 34 inches there is a coarser sand and some loose gravel. The texture of the surface soil varies in small areas from loam to loamy sand, and the depth to the looser sand or gravelly subsoil ranges from 20 to as many as 40 inches in places.

Only a few areas of the type are large enough to crop. It is low in productivity; when cropped it is particularly in need of organic matter and should receive liberal applications of farm manure or legumes should be turned under as green manures. It is acid and needs lime. The use of a phosphate fertilizer would undoubtedly prove of value.

Lamoure Silty Clay Loam (111)

The Lamoure silty clay loam is a minor type, covering only 0.1 percent of the total area. The areas occur along the south county line in sections 31 and 32 of Washington Township and Section 34 of Albion Township.

The surface soil of the type is a black silty clay loam, grading at about 1 foot into a heavier textured soil, gradually changing into a silty clay. Below 3 feet the soil is a clay, somewhat lighter in color and marked with gray and whitish streaks showing the occurrence of lime. Occasionally the lime content may be considerable even up into the surface soil, but it is always high in the subsoil.

The small areas of the type are mainly in pasture and afford excellent pasturage. When protected from overflow and well drained, it might be cultivated, but it is naturally poorly drained and frequently overflowed and hence is better left in pasture.

Muck and Peat (21)

There is a small area of muck and peat in the county, covering 0.1 percent of the total area. Only 3 small areas are mapped. The areas in Section 35 of Fremont Township consist of a dark brownish muck or peat containing about 35 to 40 percent of organic matter. The material is loose and fluffy when dry; at a depth of about 12 inches below the surface there is a blackish muck with more soil present. A coarse bunchy grass grows on the areas.

The other area is in sections 5 and 6 of Ripley Township. Here the muck soil extends only to a depth of about 2 feet and is underlaid by stiff sticky black clay. Only a thin 2 or 3-inch surface covering consists of brownish-fluffy peat. This occurs in a depression and is more or less soggy the year around, owing to lack of drainage. These peat and muck areas may be made more productive by thorough drainage, if that can be accomplished without too great expense. The use of a phosphate and a potash fertilizer would be of value. In general, the areas probably should be left in pasture.

APPENDIX

THE SOIL SURVEY OF IOWA

What soils need to make them highly productive and to keep them so, and how their needs may be supplied, are problems which are met constantly on the farm today.

To enable every farmer to solve these problems for his local conditions, a complete survey and study of the soils of the state has been undertaken, the results of which will be published in a series of county reports. This work includes a detailed survey of the soils of each county, following which all the soil types, streams, roads, railroads, etc., are accurately located on a soil map. This portion of the work is being carried on in cooperation with the Bureau of Soils of the United States Department of Agriculture.

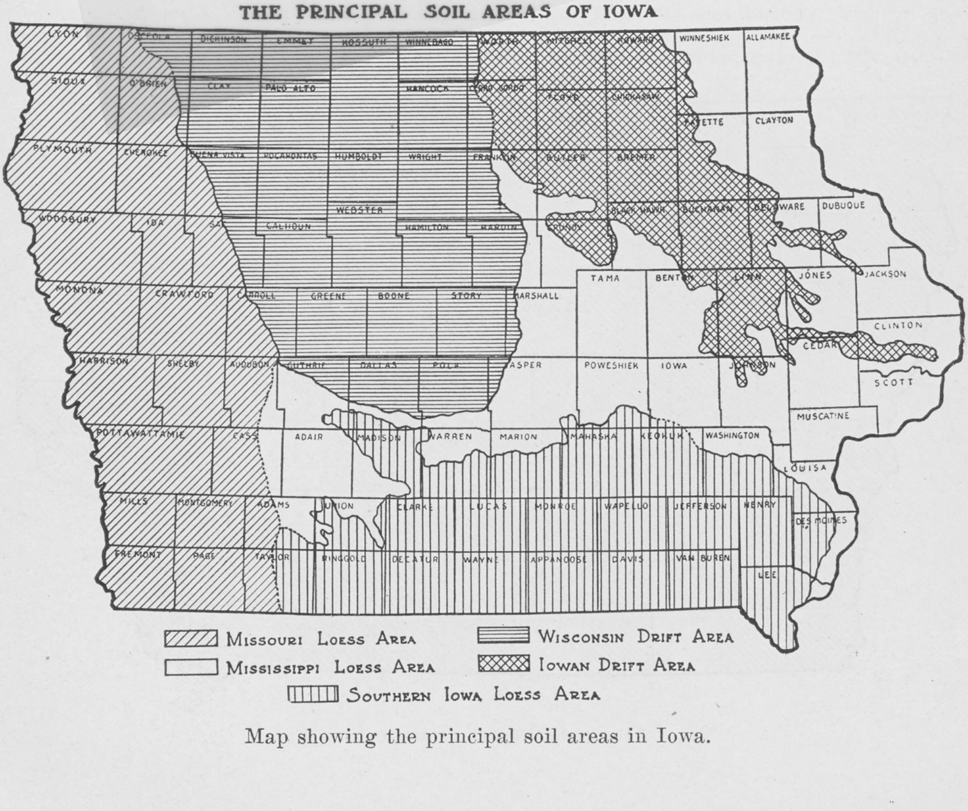
Samples of soils are taken and examined mechanically and chemically to determine their character and composition and to learn their needs. Pot experiments with these samples are conducted in the greenhouse to ascertain the value of the use of manure, fertilizers, lime and other materials on the various soils. These pot tests are followed in many cases by field experiments to check the results secured in the greenhouse. The meagerness of the funds available for such work has limited the extent of these field studies, and tests have not been possible in each county surveyed. Fairly complete results have been secured, however, on the main types in the large soil areas.

Following the survey, systems of soil management which should be adopted in the various counties and on the different soils are worked out, old methods of treatment are emphasized as necessary or their discontinuance advised, and new methods of proved value are suggested.

SOIL AREAS IN IOWA

There are five large soil areas in Iowa, the Wisconsin drift, the Iowan drift, the Missouri loess, the Mississippi loess and the Southern Iowa loess. These five divisions of the soils of the state are based on the geological force which brought about the formation of the various soil areas.

THE PRINCIPAL SOIL AREAS OF IOWA



Map showing the principal soil areas in Iowa.

With the exception of the northeastern part of the state, the whole surface of Iowa was in ages past overrun by great continental ice sheets. These great masses of ice moved slowly over the land, crushing and grinding the rocks beneath and carrying along with them the material which they accumulated in their progress. Five ice sheets invaded Iowa at different geological eras, coming from different directions and carrying, therefore, different rock material with them.

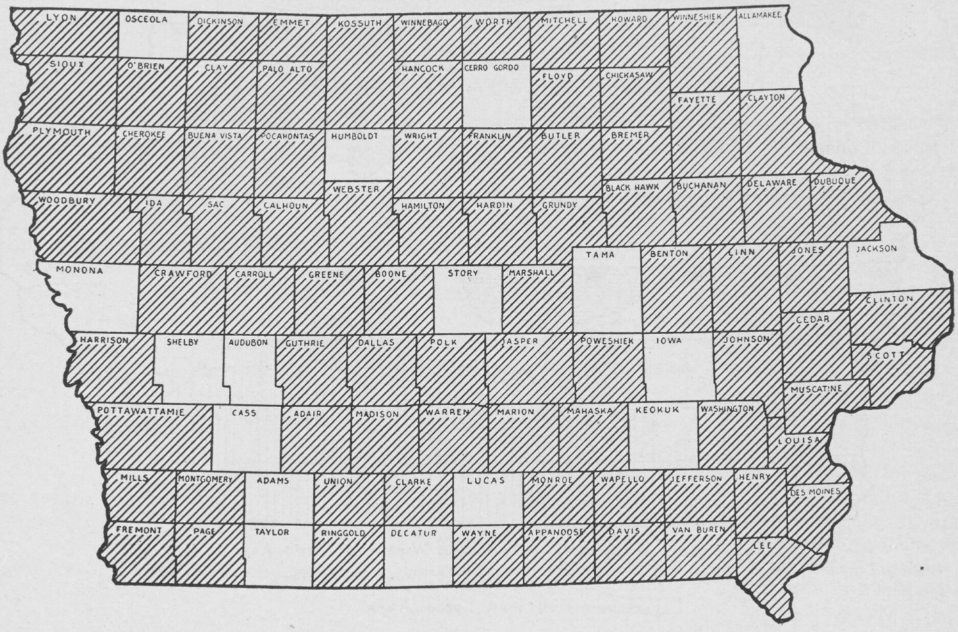
The deposit, or sheet of earth debris left after the ice of such glaciers melts, is called "glacial till" or "drift" and is easily distinguished by the fact that it is usually a rather stiff clay, containing pebbles of all sorts as well as large boulders of "nigger heads." Two of these drift areas occur in Iowa today, the Wisconsin drift and the Iowan drift, covering the north central part of the state. The soils of these two drift areas are entirely different in chemical composition, due primarily to the different ages of the two ice invasions. The Iowan drift was laid down at a much earlier period and is somewhat poorer in plant food than the Wisconsin drift soil, having undergone considerable leaching in the time which has elapsed since its formation.

The drift deposits in the remainder of the state have been covered by so-called loess soils, vast accumulations of dust-like materials which settled out of the air during a period of geological time when climatic conditions were very different from the present. These loess soils are very porous in spite of the fine texture, and they rarely contain large pebbles or stones. They present a strong contrast to the drift soils, which are somewhat heavy in texture and filled with pebbles and stones. The three loess areas in the state, the Missouri, the Mississippi and the Southern Iowa, are distinguished by differences in texture and appearance, and they vary considerably in value for farming purposes. In some sections the loess is very deep, while in other places the underlying leached till or drift is very close to the surface. The fertility of these soils and their needs are greatly influenced, therefore, by their depth.

It will be seen that the soils of the state may be roughly divided into two classes, drift soils and loess soils, and that further division may then be made into various drift and loess soils because of differences in period of formation, characteristics and general composition. More accurate information demands, however, that further divisions be made. The different drift and loess soils contain large numbers of soil types which vary among themselves, and each of these should receive special attention.

THE SOIL SURVEY BY COUNTIES

It is apparent that a general survey of the soils of the state can give only a very general idea of soil conditions. Soils vary so widely in character and composition, depending on many other factors than their source, that definite knowledge concerning their needs can be secured only by thorough and complete study of them in place in small areas. Climatic conditions, topography, depth and character of soil, chemical and mechanical composition and all other factors affecting crop production must be considered.



Map of Iowa showing the counties surveyed.

This is what is accomplished by the soil survey of the state by counties, and hence the needs of individual soils and proper systems of management may be worked out in much greater detail and be much more complete than would be possible by merely considering the large areas separated on the basis of their geological origin. In other words, while the unit in the general survey is the geological history of the soil area, in the soil survey by counties or any other small area, the unit is the soil type.

GENERAL SOIL CHARACTERISTICS

Soil types possess more or less definite characteristics which may be determined largely in the field, although some laboratory study is necessary for final disposition. Usually the line of separation between adjoining soil types is distinct and it is a simple matter to locate the type boundaries. In some cases, however, there is a gradation from one type to another and then the boundaries may be fixed only with great difficulty. The error introduced into soil survey work from this source is very small and need cause little concern.

The factors which must be taken into account in establishing soil types have been well enumerated by the Illinois Experiment Station in its Soil Report No. 1. They are:

1. The geological origin of the soil, whether residual, glacial, loessial, alluvial, colluvial or cumulose.
2. The topography or lay of the land.
3. The structure or depth and character of the surface, subsurface and subsoil.
4. The physical and mechanical composition of different strata composing the soil, as the percentages of gravel, sand, silt, clay and organic matter which they contain.
5. The texture or porosity, granulation, friability, plasticity, etc.
6. The color of the strata.
7. The natural drainage.
8. The agricultural value based upon its natural productiveness.
9. Native vegetation.
10. The ultimate chemical composition and reaction.

The common soil constituents may be given as follows:†

Organic matter { All partially destroyed or decomposed vegetable and animal matter.

Inorganic matter {
Stones—over 32 mm.*
Gravel—32—2.0 mm.
Very coarse sand—2.0—1.0 mm.
Coarse sand —1.0—0.5 mm.
Medium sand —0.5—0.25 mm.
Fine sand —0.25—0.10 mm.
Very fine sand—0.10—0.05 mm.
Silt—0.05—0.00 mm.

SOILS GROUPED BY TYPES

The general groups of soils by types are indicated thus by the Bureau of Soils.

Peats—Consisting of 35 percent or more of organic matter, sometimes mixed with more or less sand or soil.

Peaty Loams—15 to 35 percent organic matter mixed with much sand and silt and a little clay.

Mucks—25 to 35 percent of partly decomposed organic matter mixed with much clay and some silt.

Clays—Soils with more than 30 percent clay, usually mixed with much silt; always more than 50 percent silt and clay.

Silty Clay Loams—20 to 30 percent clay and more than 50 percent silt.

Clay Loams—20 to 30 percent clay and less than 50 percent silt and some sand.

Silt Loams—20 percent clay and more than 50 percent silt mixed with some sand.

Loams—Less than 20 percent clay and less than 50 percent silt and from 30 to 50 percent sand.

Sandy Clays—20 percent silt and small amounts of clay up to 30 percent.

Fine Sandy Loams—More than 50 percent fine sand and very fine sand mixed with less than 25 percent very coarse sand, coarse sand and medium sand, much silt and a little clay; silt and clay 20 to 50 percent.

Sandy Loams—More than 25 percent very coarse, coarse and medium sand; silt and clay 20 to 50 percent.

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* 25mm. equals 1 in. † Bureau of Soils Handbook.

Very Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Fine Sand—More than 50 percent fine sand and less than 25 percent very coarse, coarse and medium sand, less than 20 percent silt and clay.

Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent fine sand, less than 20 percent silt and clay.

Coarse Sand—More than 25 percent very coarse, coarse and medium sand, less than 50 percent of other grades, less than 20 percent silt and clay.

Gravelly Loams—25 to 50 percent very coarse sand and much sand and some silt.

Gravels—More than 50 percent very coarse sand.

Stony Loams—A large number of stones over 1 inch in diameter.

METHODS USED IN THE SOIL SURVEY

It may be of some interest to state briefly the methods which are followed in the field in surveying the soils.

As has been indicated, the completed map is intended to show the accurate location and boundaries, not only of all soil types, but also of the streams, roads, railroads, etc.

The first step, therefore, is the choice of an accurate base map, and any official map of the county may be chosen for this purpose. Such maps are always checked to correspond correctly with the land survey. The location of every stream, road and railroad on the map is likewise carefully verified and corrections are frequently necessary. When an accurate base map is not available the field party must first prepare one.

The section is the unit area by which each county is surveyed and mapped. The distances in the roads are determined by an odometer attached to the vehicle, and in the field by pacing, which is done with accuracy. The directions of the streams, roads, railroads, etc., are determined by the use of the compass and the plane table. The character of the soil types is ascertained in the section by the use of the auger, an instrument for sampling both the surface soil and the subsoil. The boundaries of each type are then ascertained accurately in the section and indicated on the map. Many samplings are frequently necessary, and individual sections may contain several soil types and require much time for mapping. In other cases, the entire section may contain only one soil type, which fact is readily ascertained, and in that case mapping may proceed rapidly.

When one section is completed, the party passes to the next section and the location of all soil types, streams, etc., in that section is then checked with their location in the adjoining area just mapped. Careful attention is paid to the topographic features of the area, or the "lay of the land," for the character of the soils is found to correspond very closely to the conditions under which they occur.

The field party is composed of two men, and all observations, measurements and soil type boundaries are compared and checked by each man.

The determinations of soil types are verified also by inspections and by consultation with those in charge of the work at the Bureau of Soils and at the Iowa Agricultural Experiment Station. When the entire county is completed, all the section maps or field sheets are assembled and any variations or questionable boundaries are verified by further observations of the particular area.

The completed map, therefore, shows as accurately as possible all soils and soil boundaries, and it constitutes also an exact map of the county.